US012036375B2

(12) United States Patent
Heilman et al.

(10) Patent No.: US 12,036,375 B2
(45) Date of Patent: Jul. 16, 2024

(54) **METHODS AND SYSTEMS FOR TREATING HYDROCEPHALUS**

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(73) Assignee: **CereVasc, Inc.**, Auburndale, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1296 days.

(21) Appl. No.: **16/337,346**

(22) PCT Filed: **Oct. 11, 2017**

(86) PCT No.: **PCT/US2017/056227**
§ 371 (c)(1),
(2) Date: **Mar. 27, 2019**

(87) PCT Pub. No.: **WO2018/071600**
PCT Pub. Date: **Apr. 19, 2018**

(65) **Prior Publication Data**
US 2020/0030588 A1 Jan. 30, 2020

Related U.S. Application Data

(63) Continuation of application No. PCT/US2016/059592, filed on Oct. 28, 2016.
(Continued)

(51) **Int. Cl.**
A61M 27/00 (2006.01)
A61F 2/95 (2013.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A61M 27/006*** (2013.01); ***A61M 25/0051*** (2013.01); ***A61M 25/0108*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC A61M 27/006; A61M 25/0051; A61M 25/0108; A61M 25/0113; A61M 25/0147;
(Continued)

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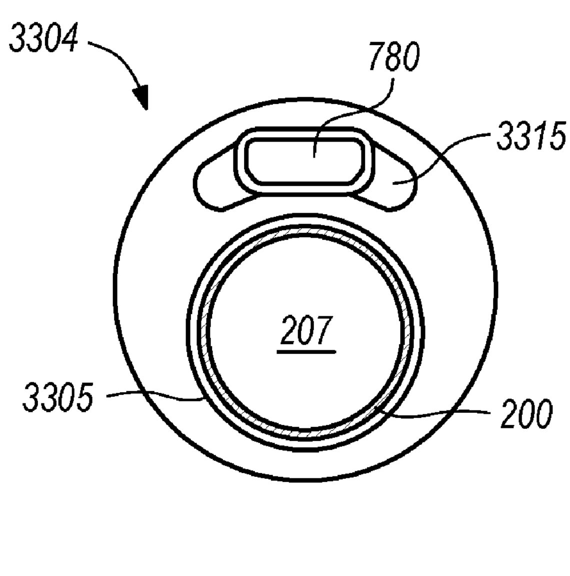
(57) **ABSTRACT**

An endovascular shunt implantation system includes a guide member configured for being deployed in an inferior petrosal sinus, and a delivery catheter movably coupled to the guide member, wherein a distal end of the delivery catheter includes a tissue penetrating element. A guard is disposed over the tissue penetrating element, the guard having an open distal end portion including an inner surface feature configured to deflect the tissue penetrating element away from the guide member when the tissue penetrating element
(Continued)



is translated distally relative to the guard. A shunt delivery shuttle is positioned within, and is movable relative to, the delivery catheter, the shunt delivery shuttle having a distal portion configured to collapse around an elongate shunt body to thereby transport the shunt body through the delivery catheter, wherein the distal portion self-expands to release the shunt body when the distal shuttle portion is advanced out of the delivery catheter.

20 Claims, 93 Drawing Sheets

Related U.S. Application Data

(60) Provisional application No. 62/473,729, filed on Mar. 20, 2017, provisional application No. 62/406,825, filed on Oct. 11, 2016.

(51) **Int. Cl.**
A61M 25/00 (2006.01)
A61M 25/01 (2006.01)
A61M 25/06 (2006.01)
A61M 25/09 (2006.01)

(52) **U.S. Cl.**
CPC ***A61M 25/0113*** (2013.01); ***A61M 25/0147*** (2013.01); ***A61M 25/0618*** (2013.01); ***A61M 25/065*** (2013.01); ***A61M 25/09041*** (2013.01); *A61M 2025/09116* (2013.01); *A61M 2210/0687* (2013.01)

(58) **Field of Classification Search**
CPC A61M 25/0618; A61M 25/065; A61M 25/09041; A61M 2025/09116; A61M 2210/0687
See application file for complete search history.

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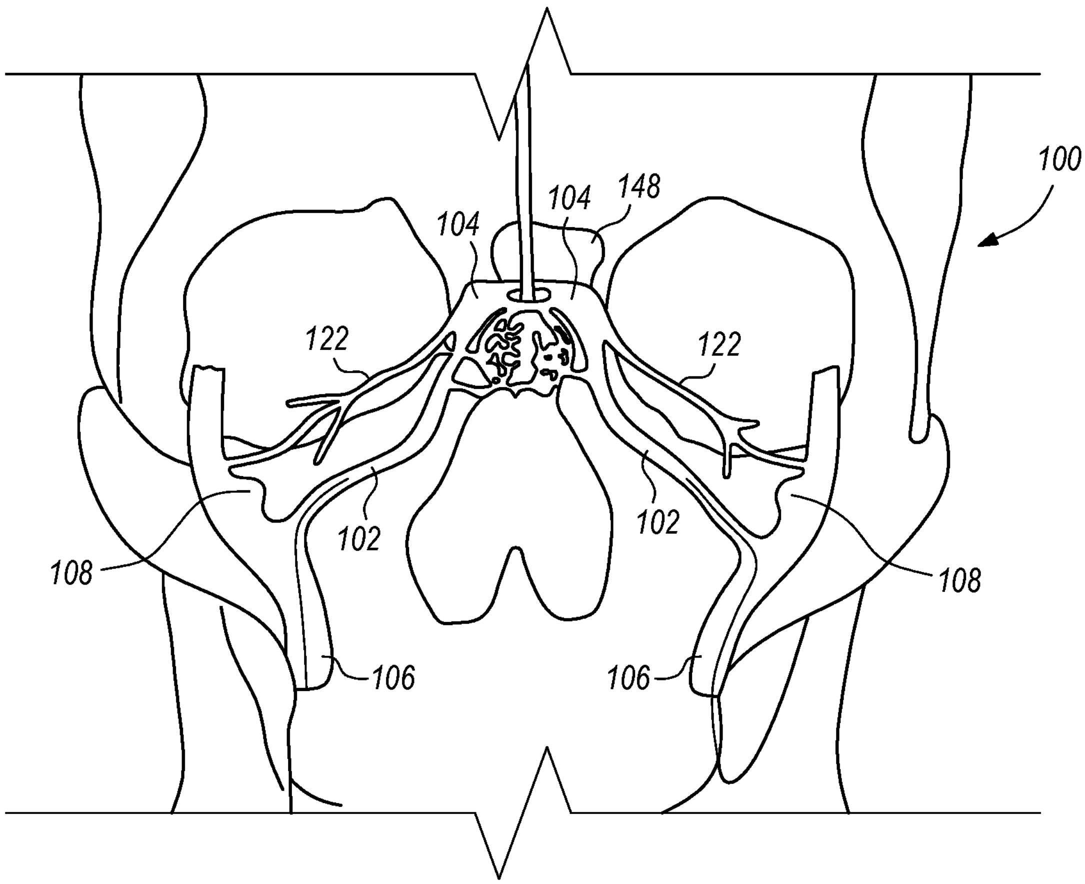
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FIG. 1

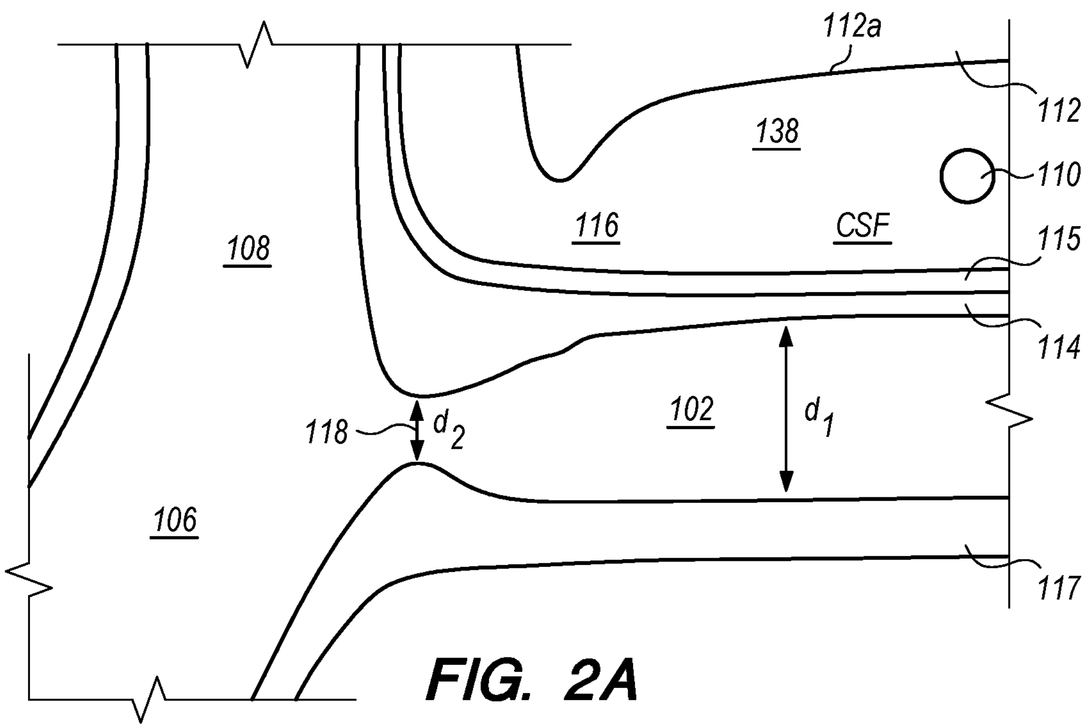
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FIG. 2A

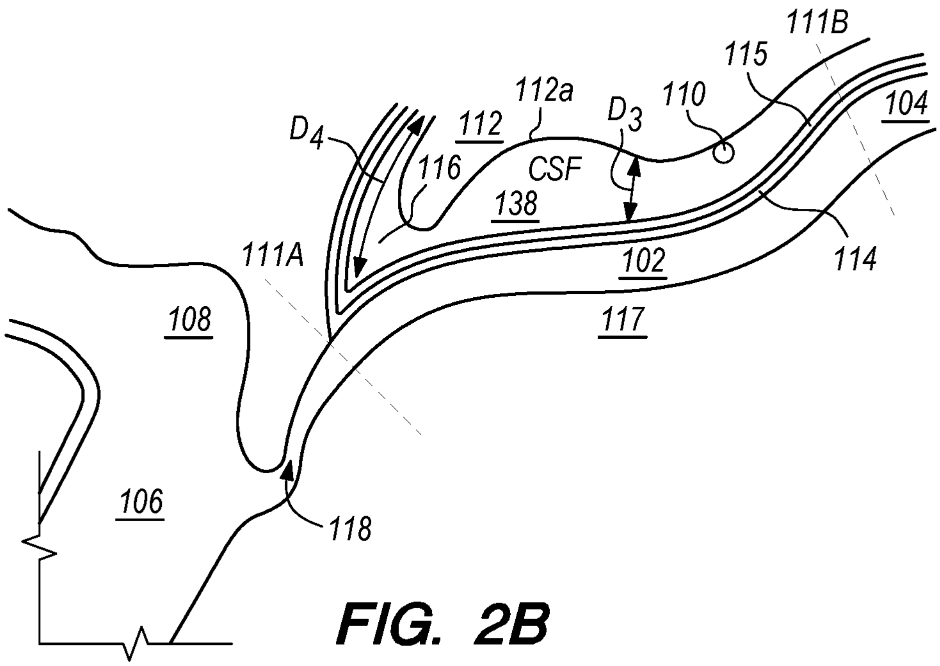
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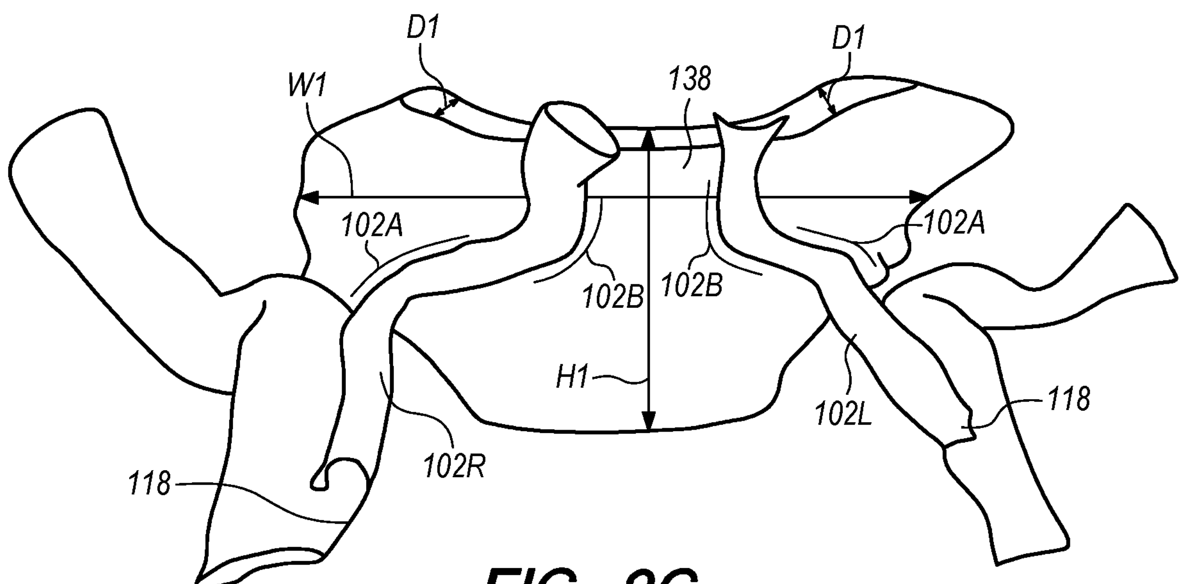
FIG. 2B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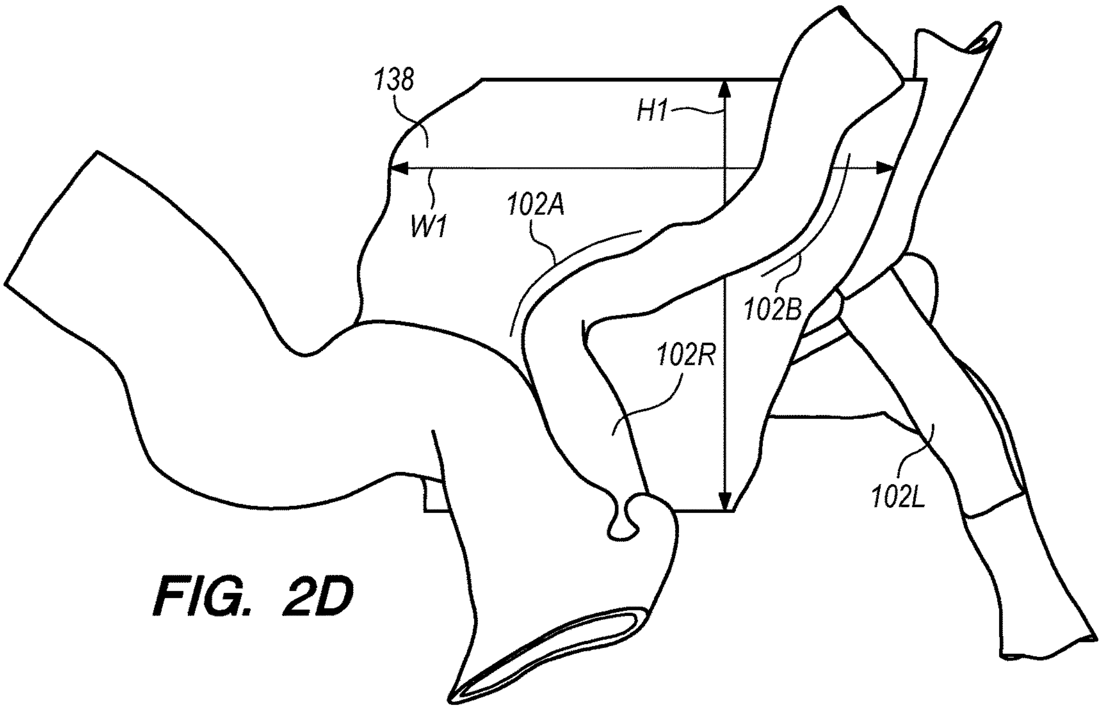


FIG. 2D

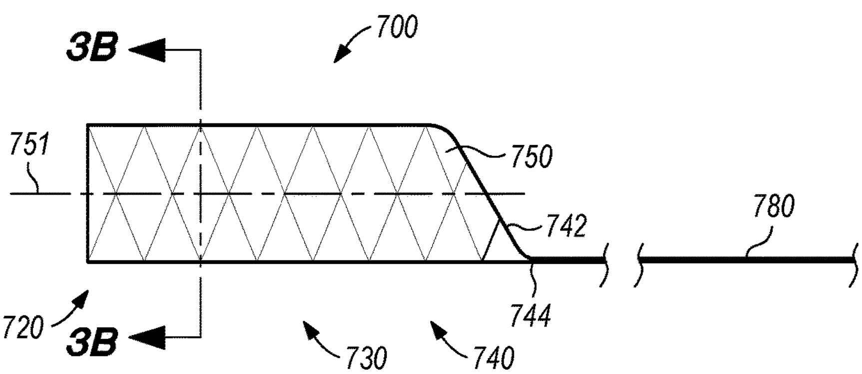


FIG. 3A

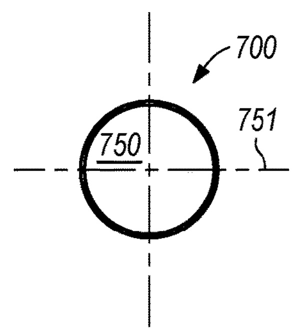


FIG. 3B

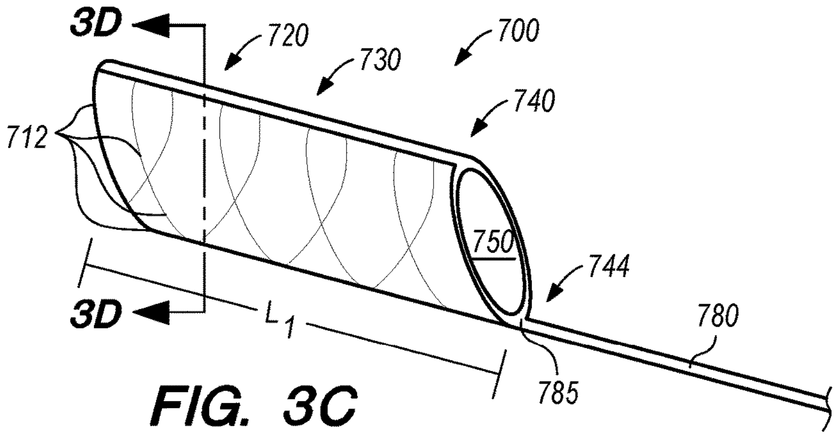


FIG. 3C

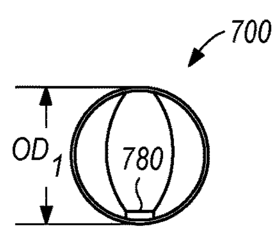


FIG. 3D

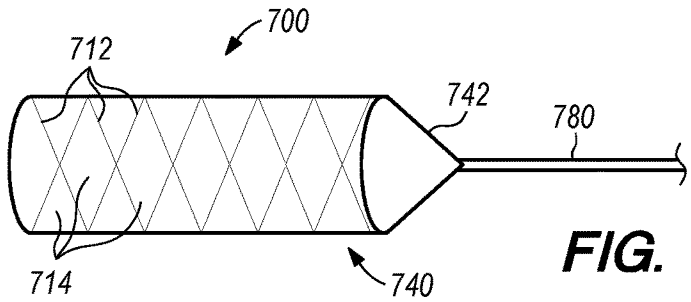


FIG. 3E

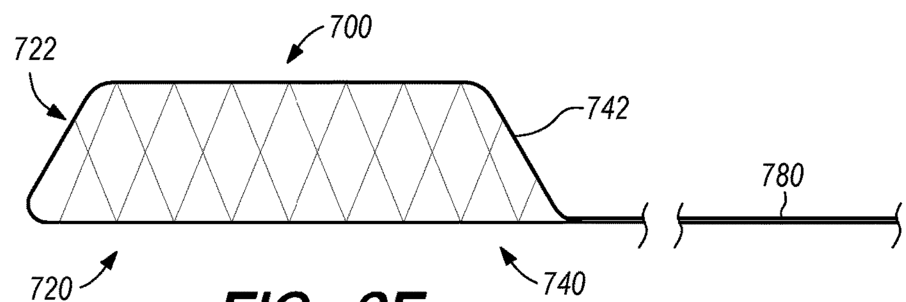


FIG. 3F

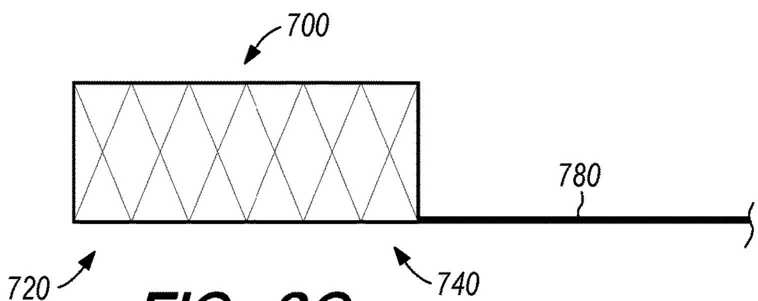


FIG. 3G

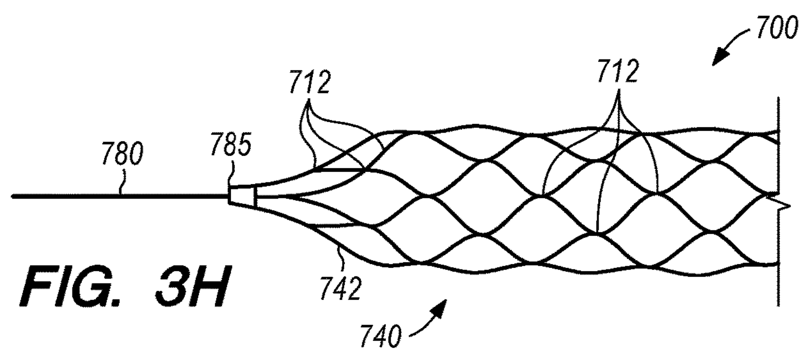


FIG. 3H

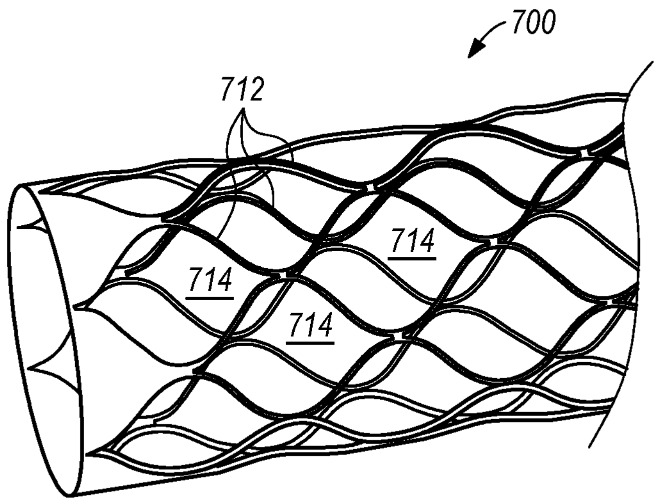


FIG. 3I

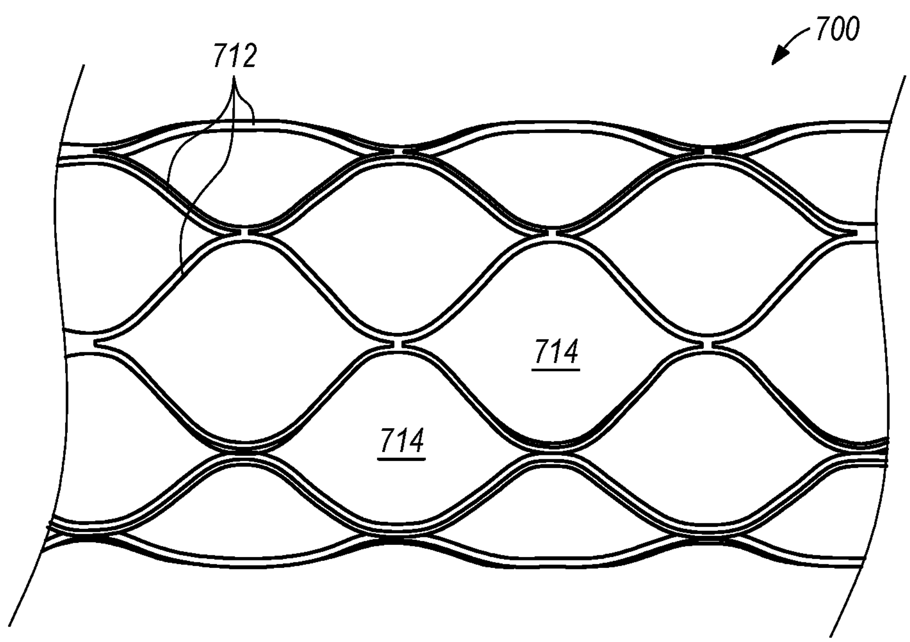


FIG. 3J

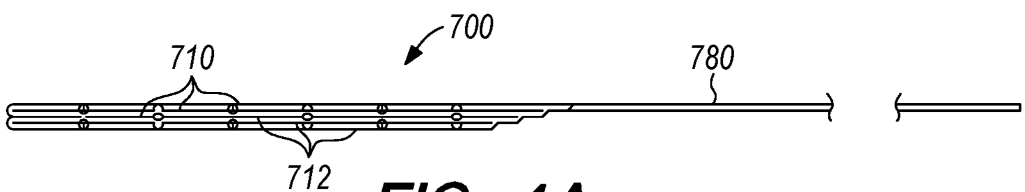


FIG. 4A

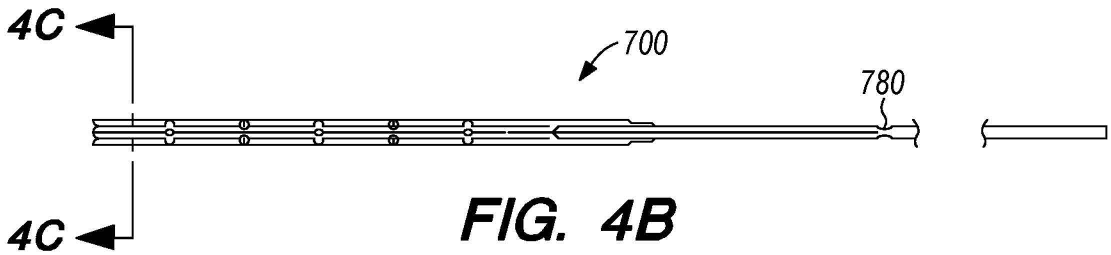


FIG. 4B

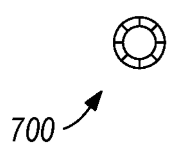


FIG. 4C

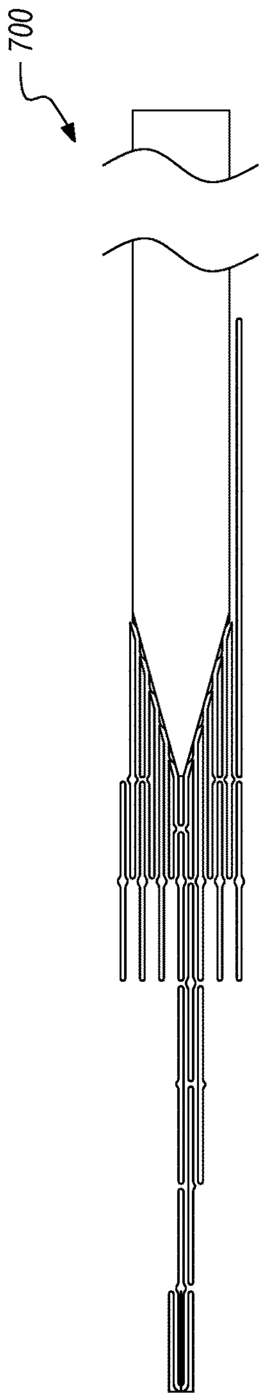


FIG. 5A

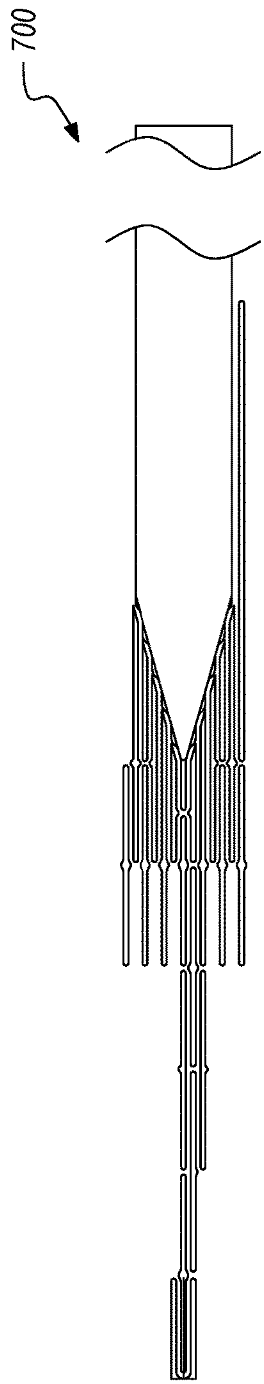


FIG. 5B

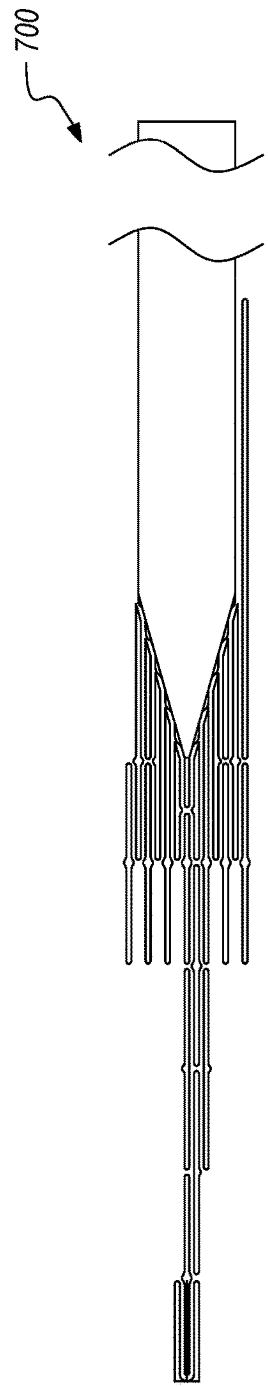


FIG. 5C

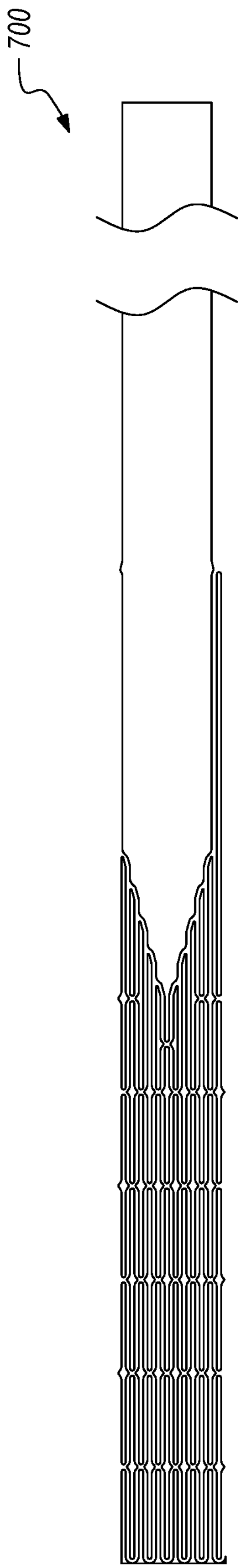


FIG. 5D

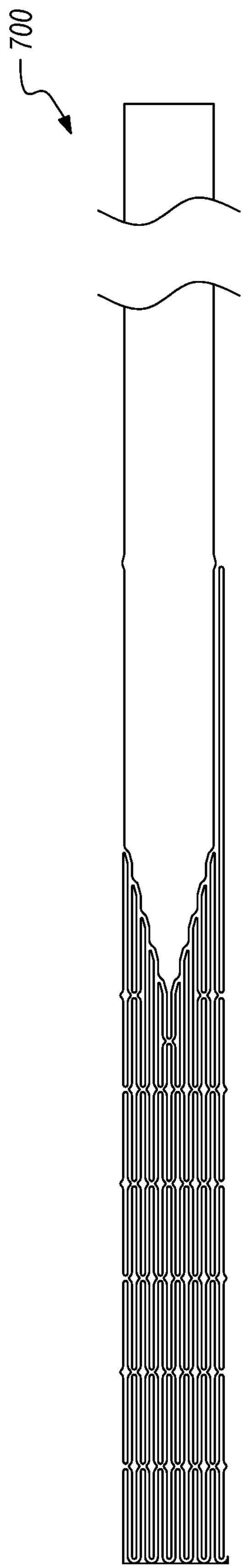


FIG. 5E

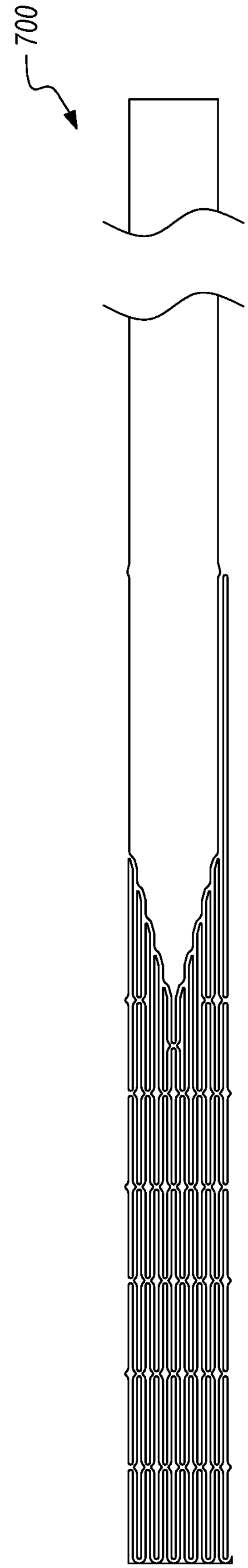


FIG. 5F

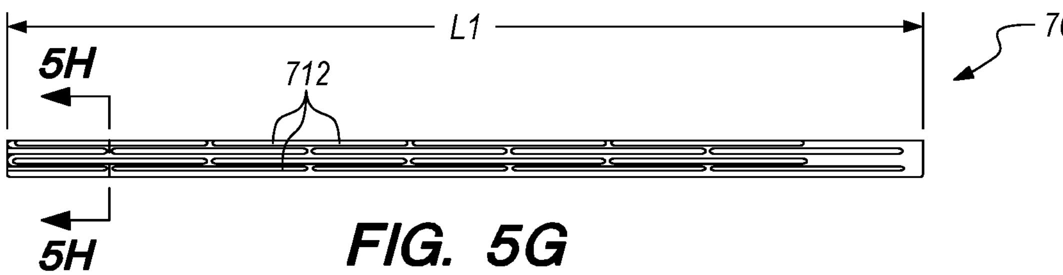


FIG. 5G

FIG. 5H

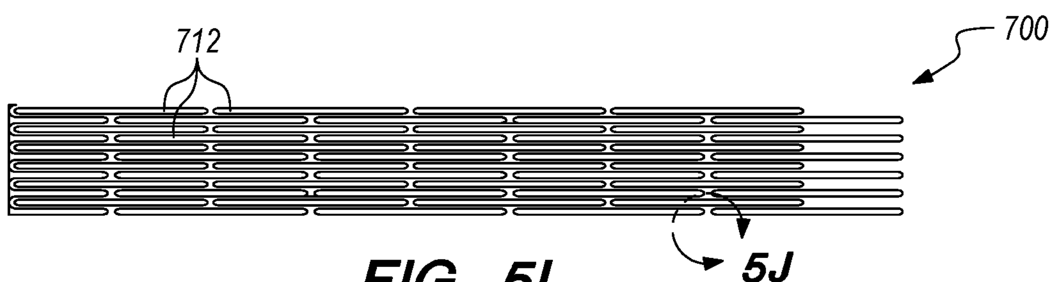


FIG. 5I

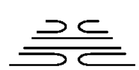


FIG. 5J

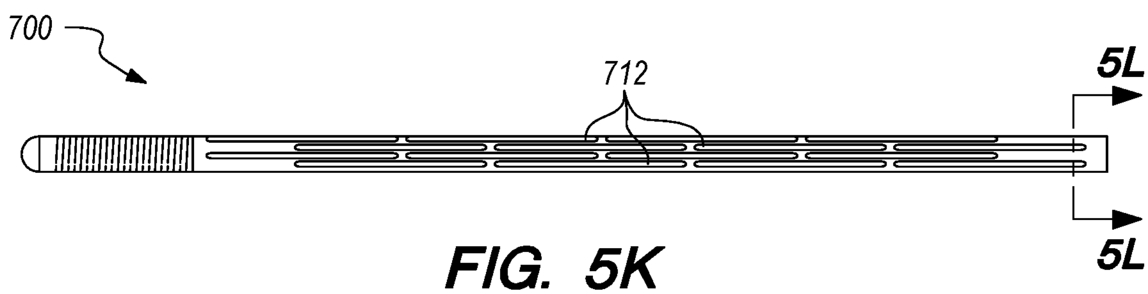


FIG. 5K

FIG. 5L

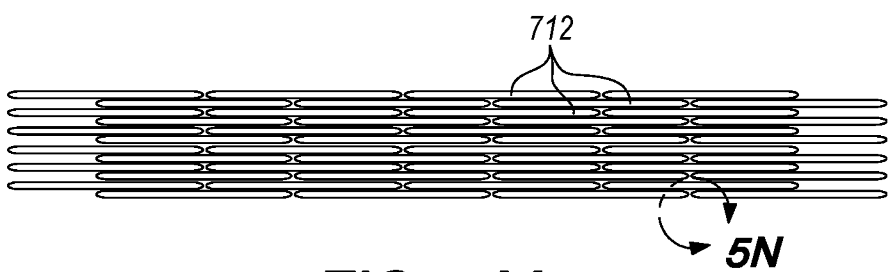


FIG. 5M

FIG. 5N

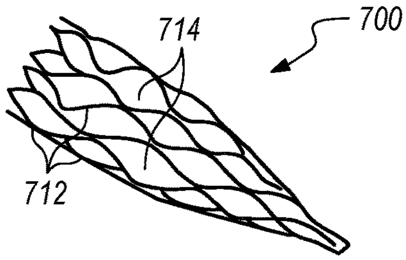


FIG. 5O

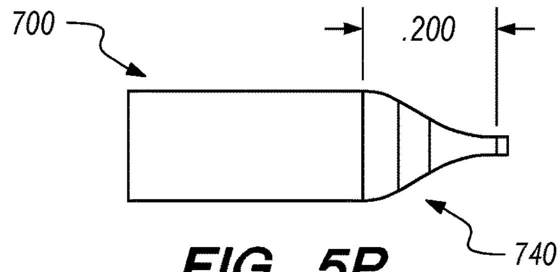


FIG. 5P

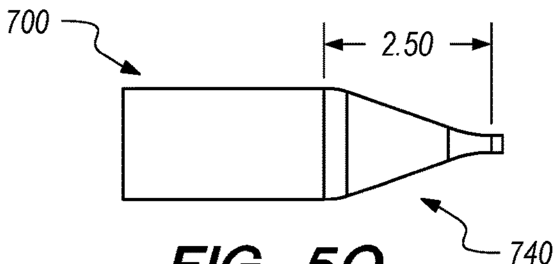


FIG. 5Q

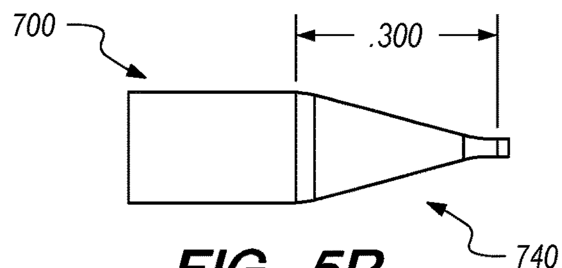


FIG. 5R

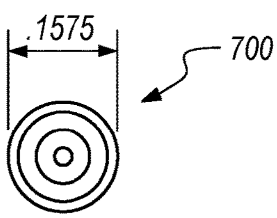


FIG. 5S

DASH NO.	TRANSITION LENGTH
-01	0.200
-02	0.250
-03	0.300

FIG. 5T

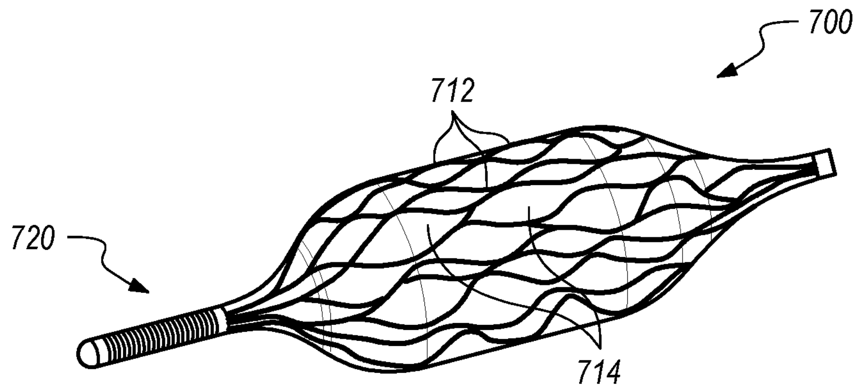


FIG. 5U

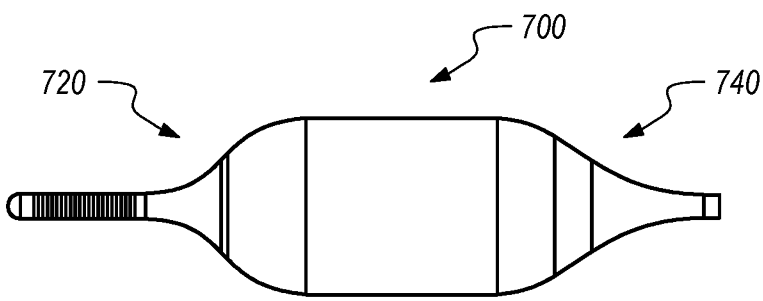


FIG. 5V

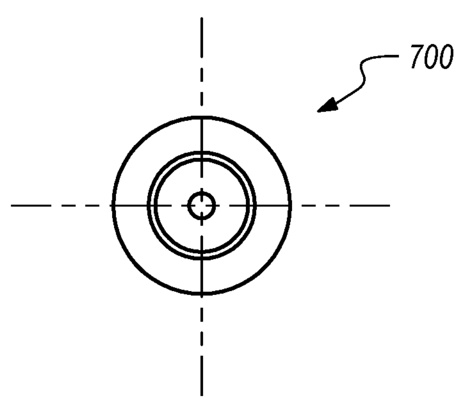


FIG. 5W

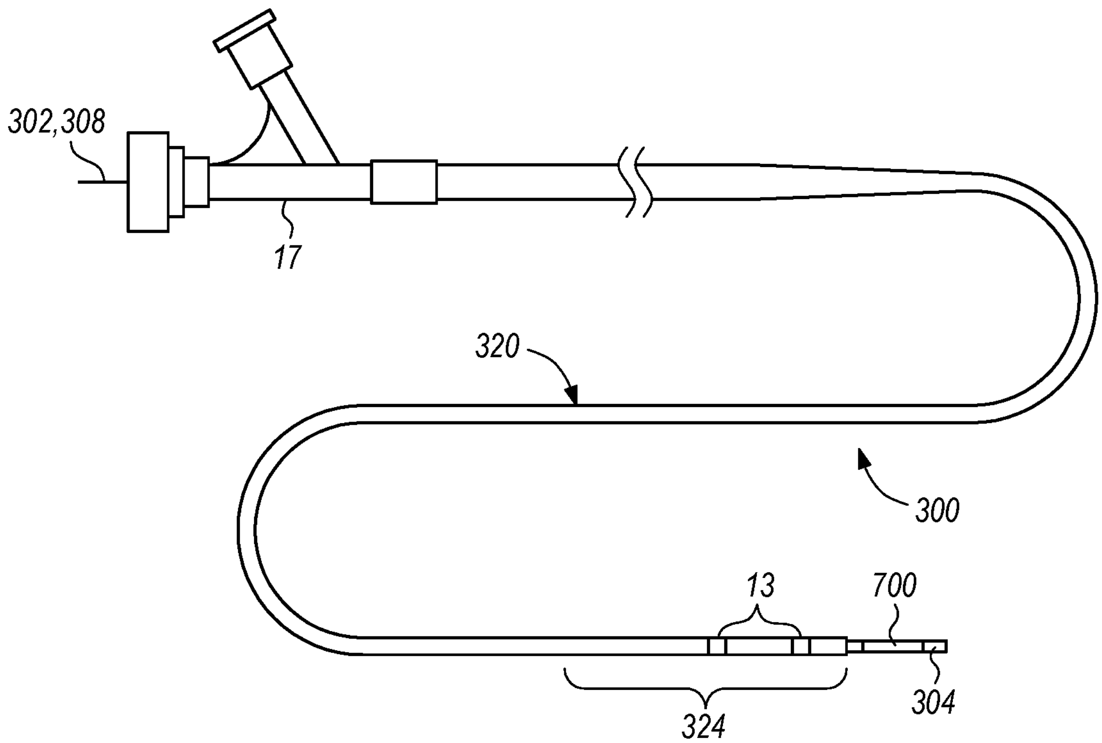


FIG. 6

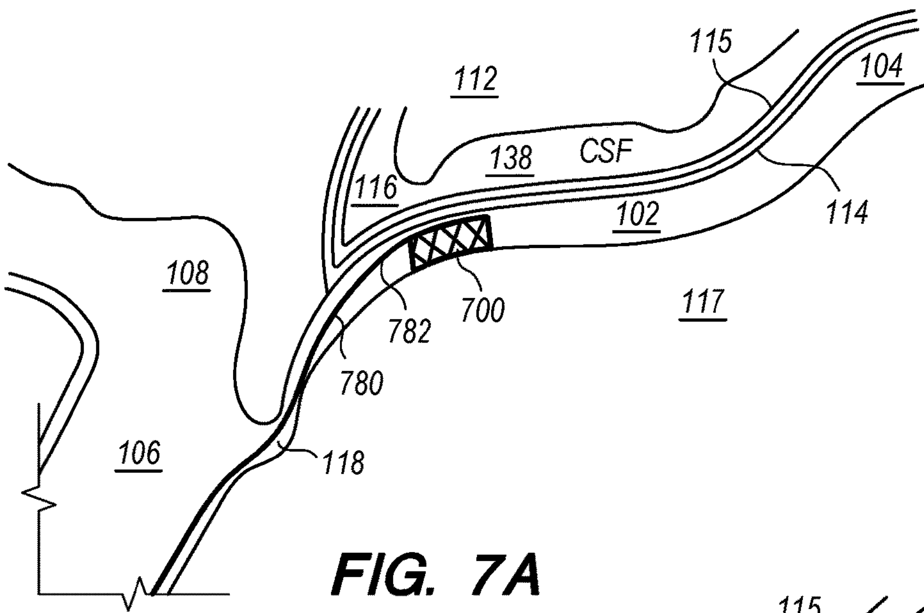


FIG. 7A

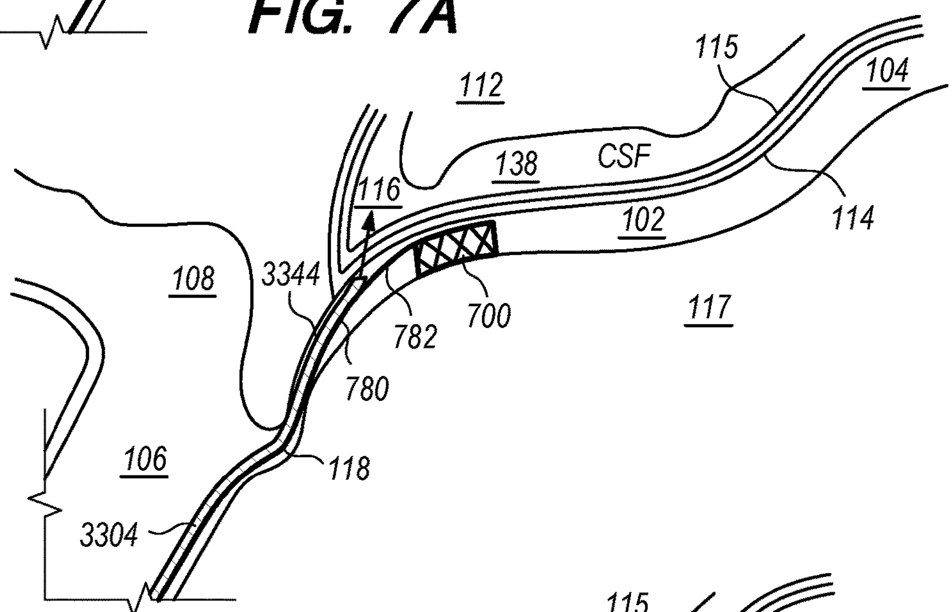


FIG. 7B

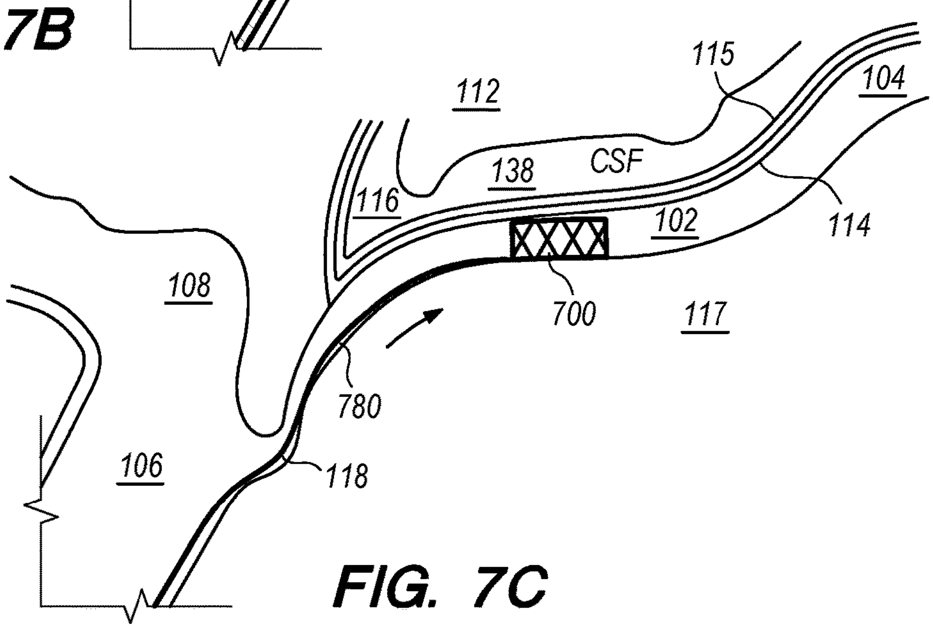


FIG. 7C

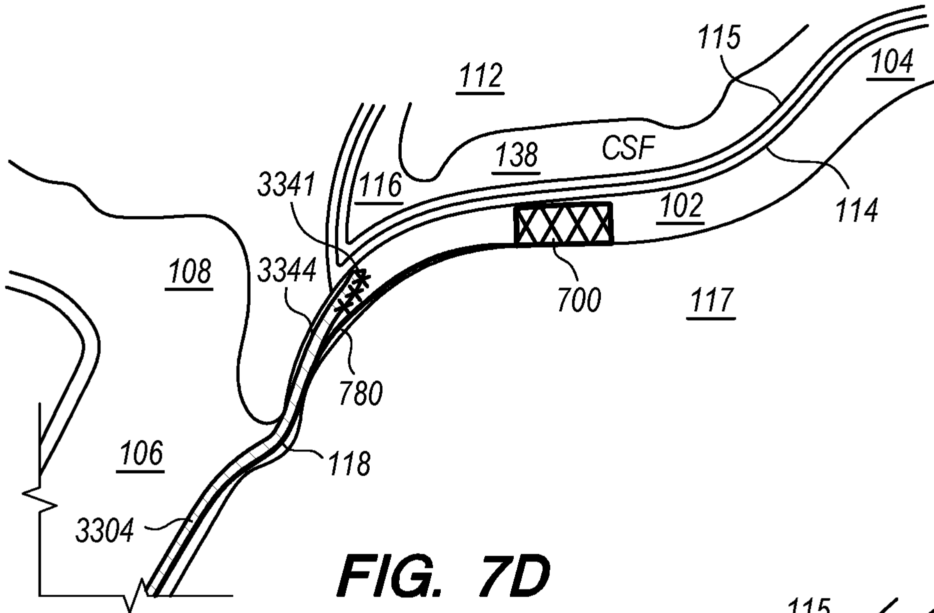


FIG. 7D

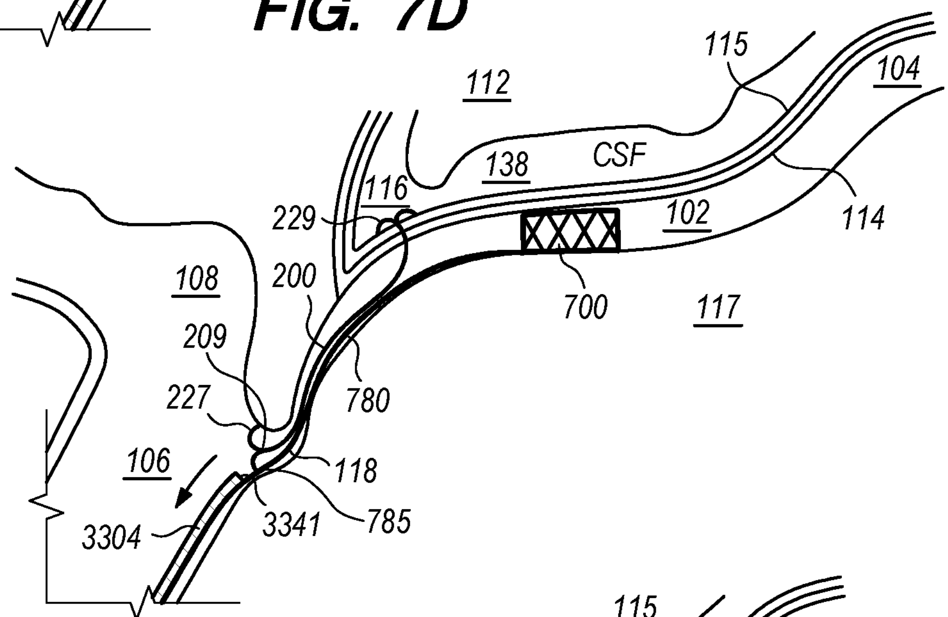


FIG. 7E

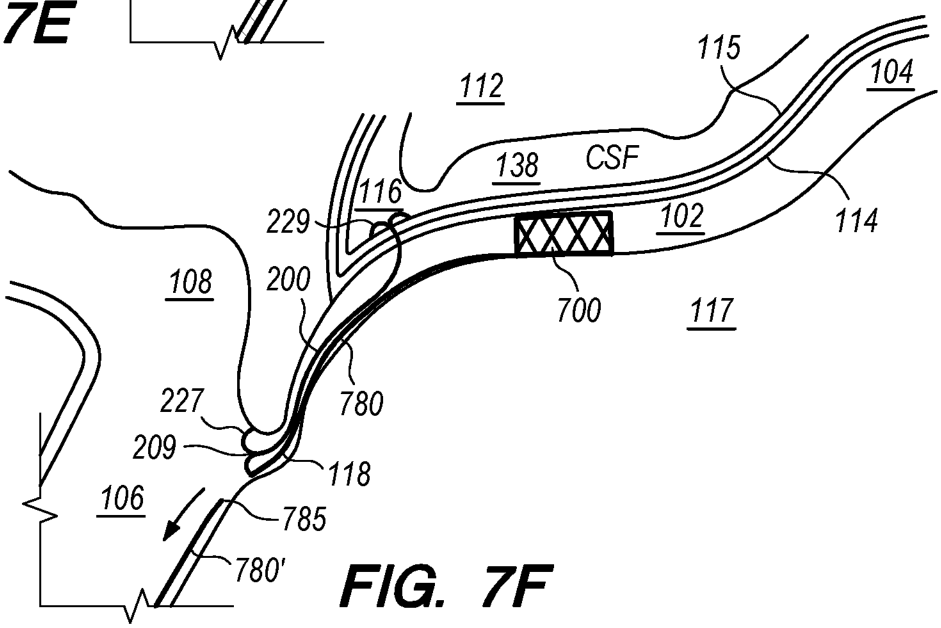


FIG. 7F

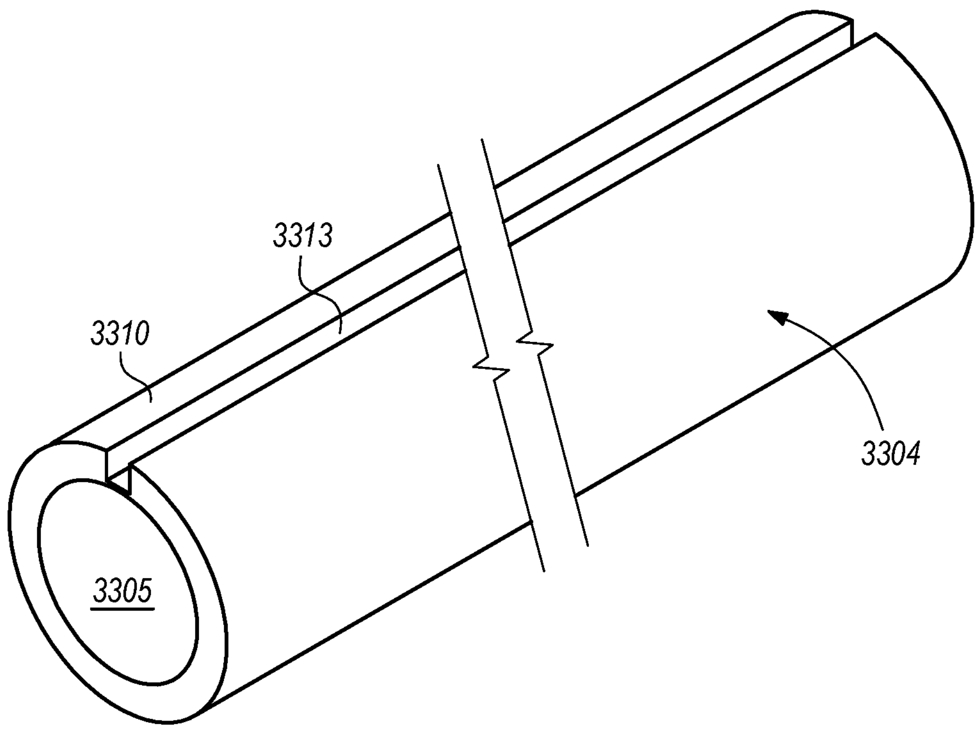


FIG. 8A

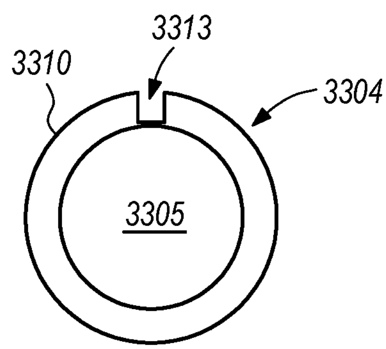


FIG. 8B

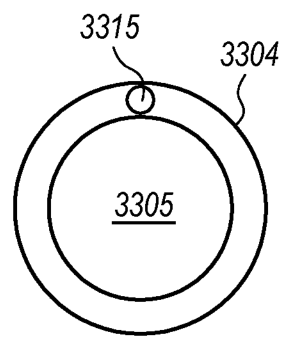


FIG. 9

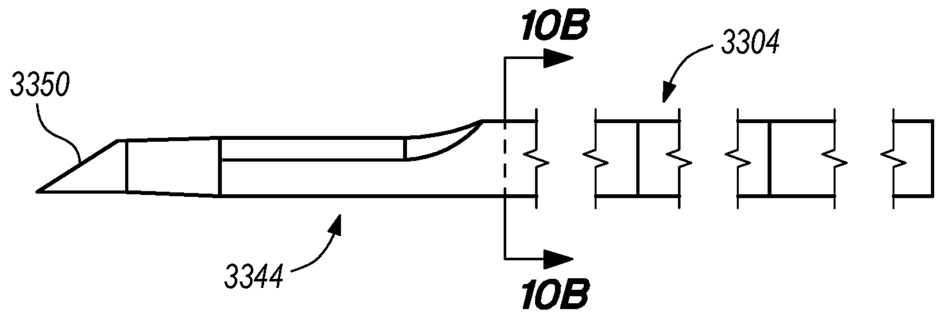


FIG. 10A

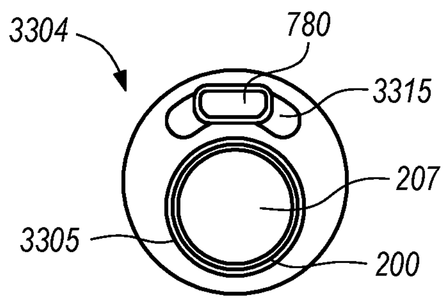


FIG. 10B

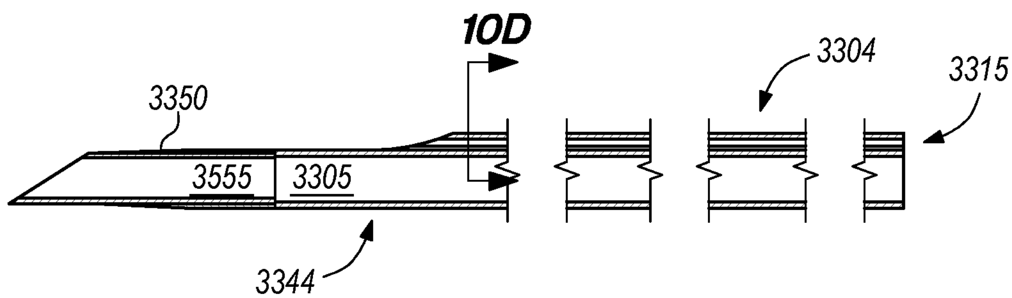


FIG. 10C

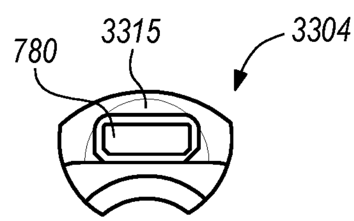


FIG. 10D

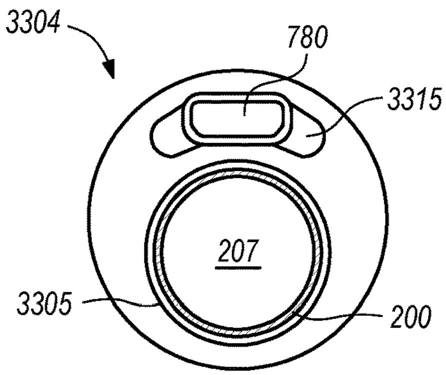


FIG. 10E

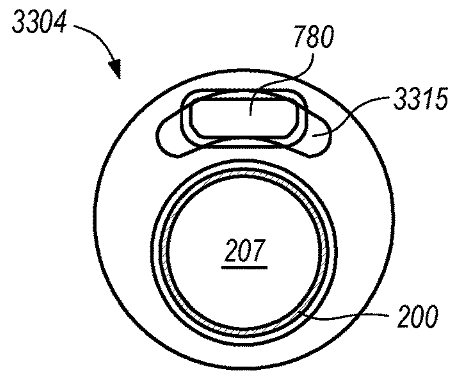


FIG. 10F

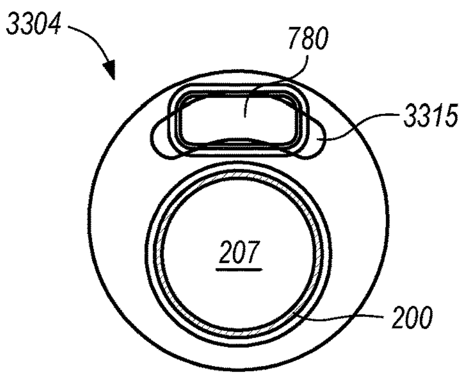


FIG. 10G

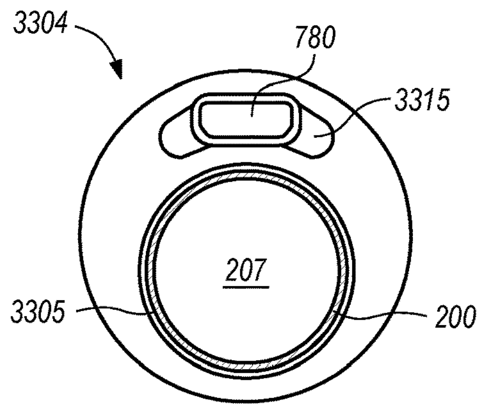


FIG. 10H

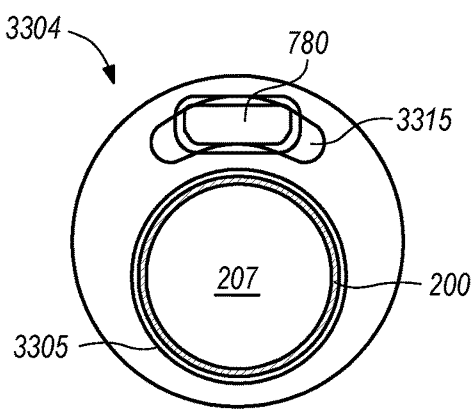


FIG. 10I

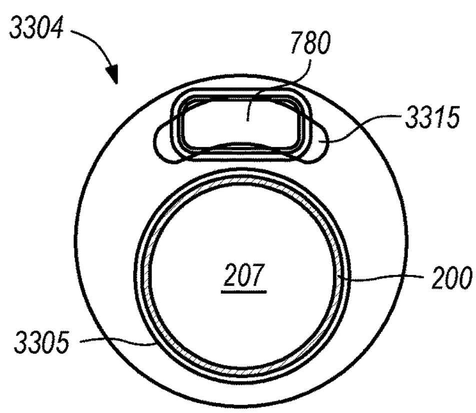


FIG. 10J

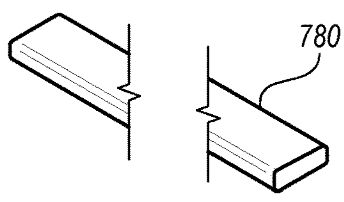


FIG. 11

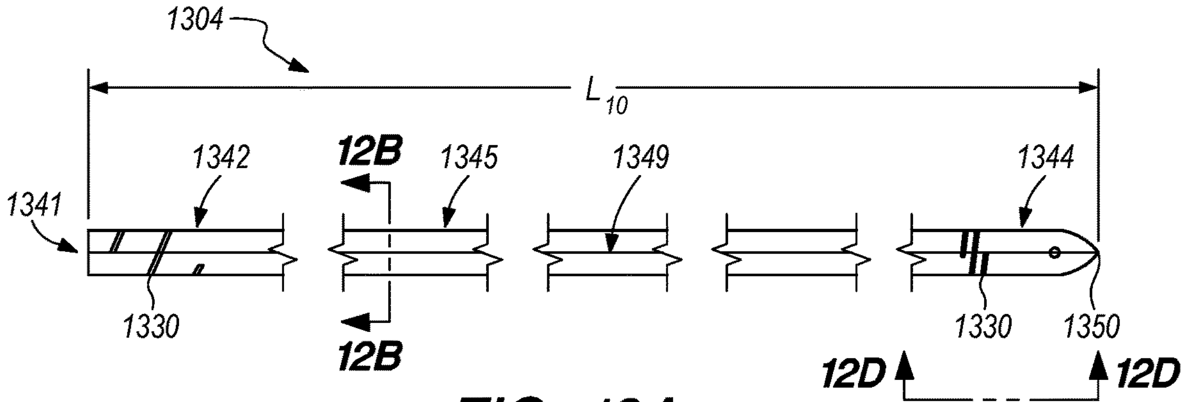


FIG. 12A

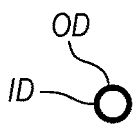


FIG. 12B

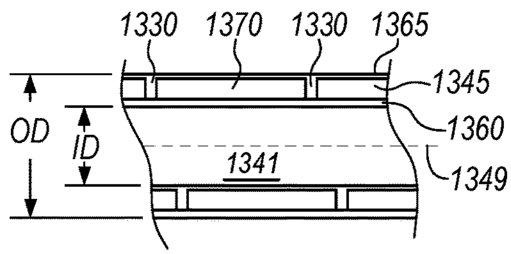


FIG. 12C

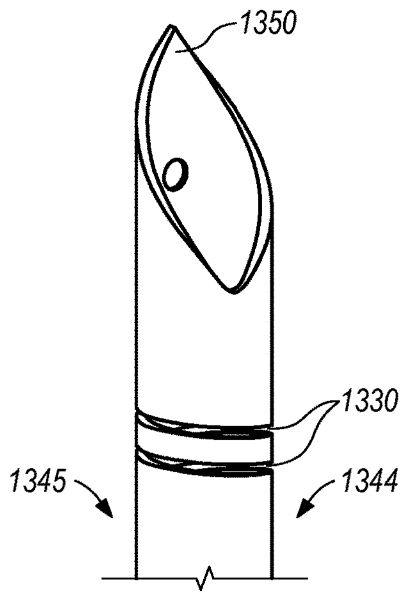


FIG. 12D

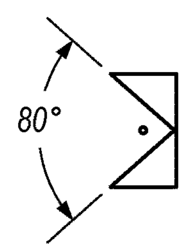
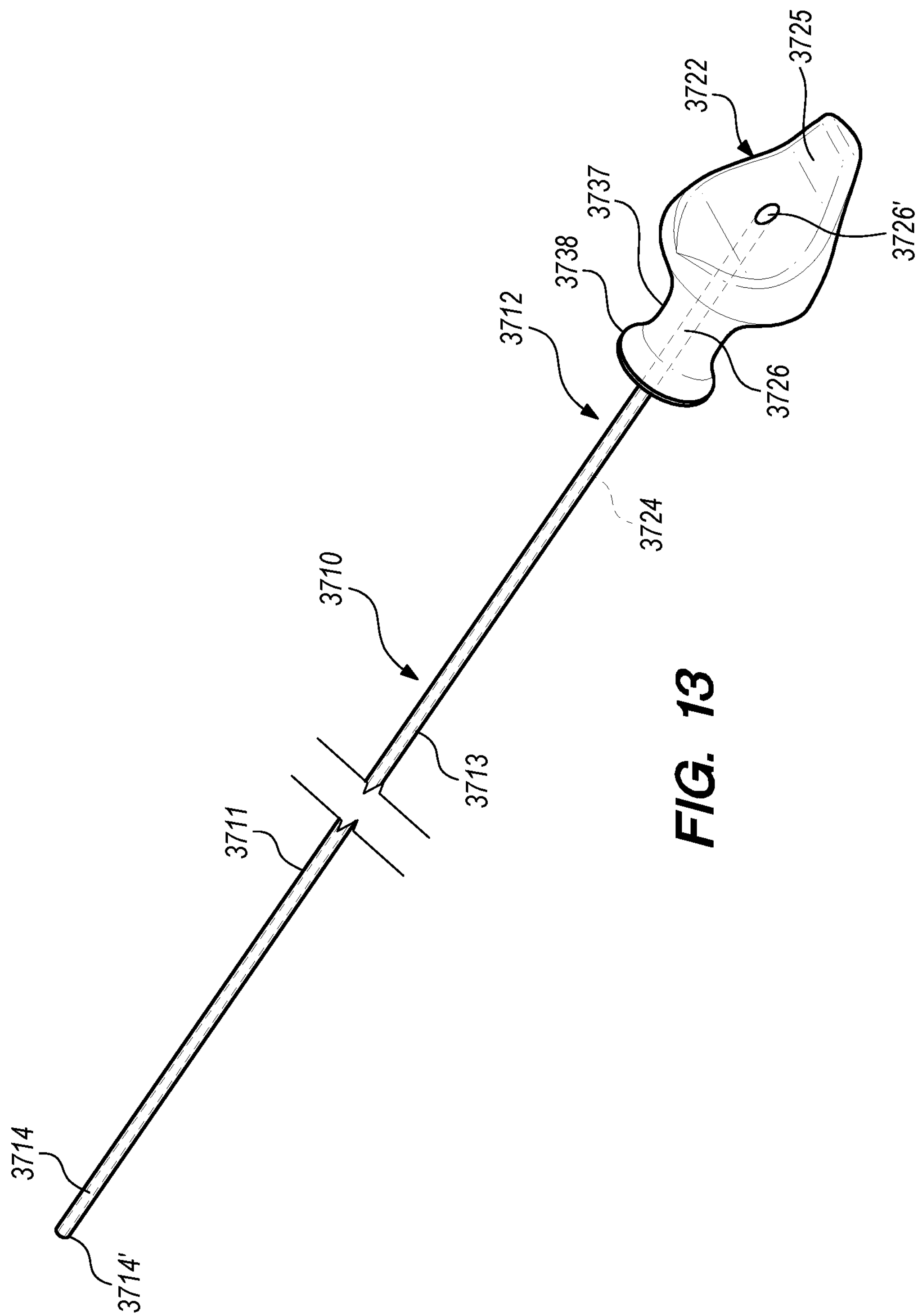


FIG. 12E


3725
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3714
3714'

FIG. 13

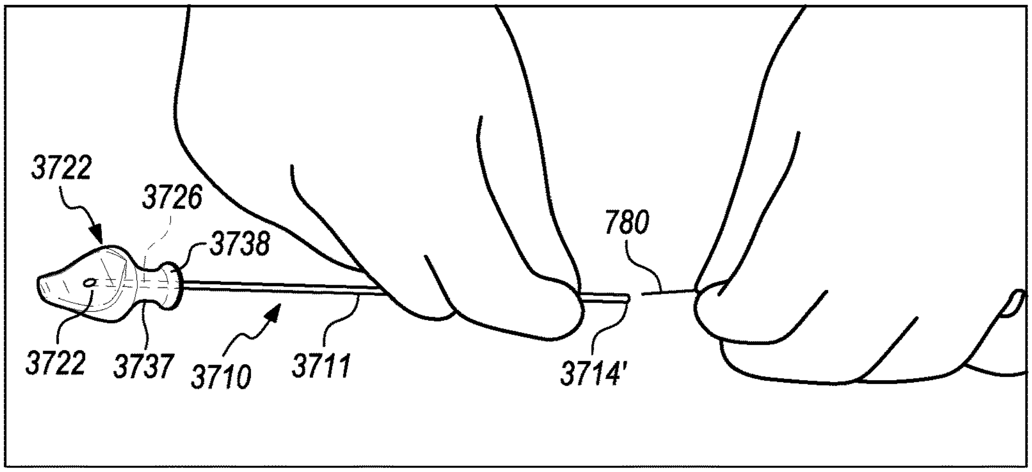


FIG. 14A

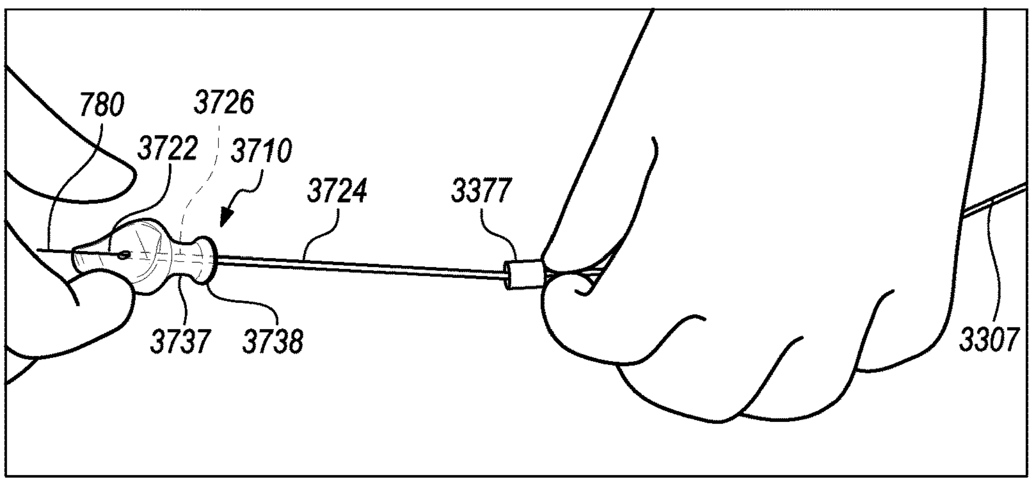


FIG. 14B

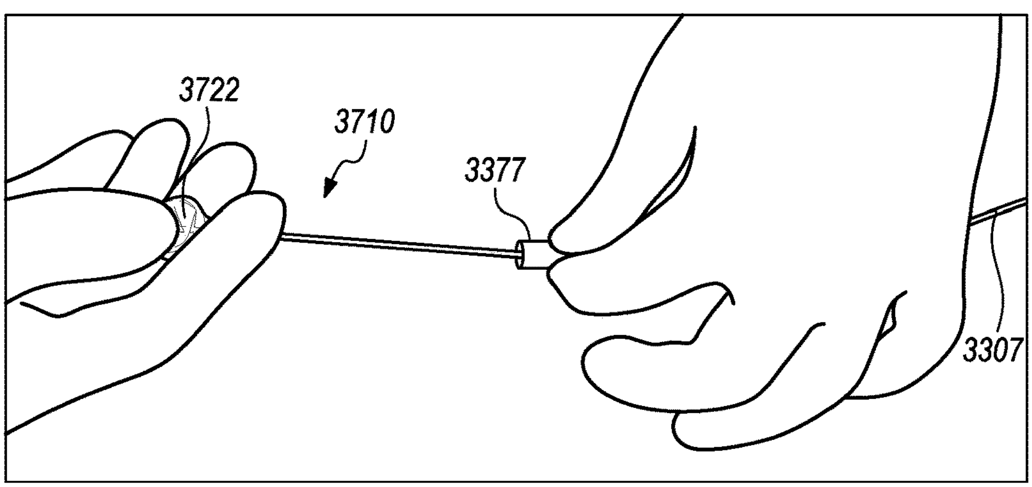


FIG. 14C

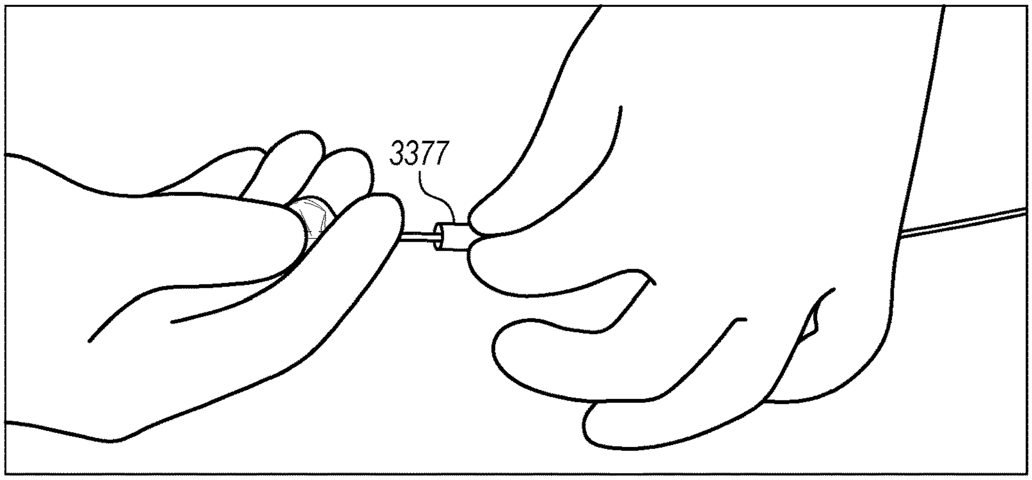


FIG. 14D

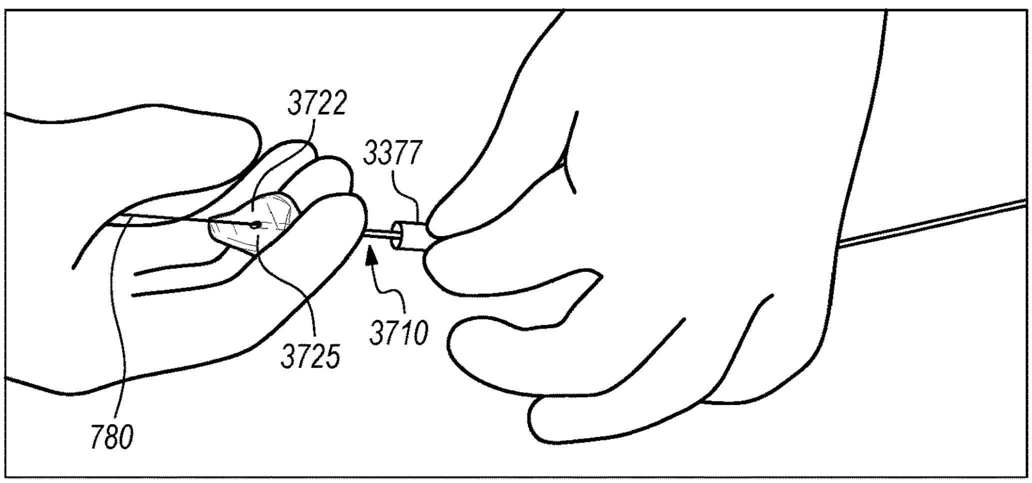


FIG. 14E

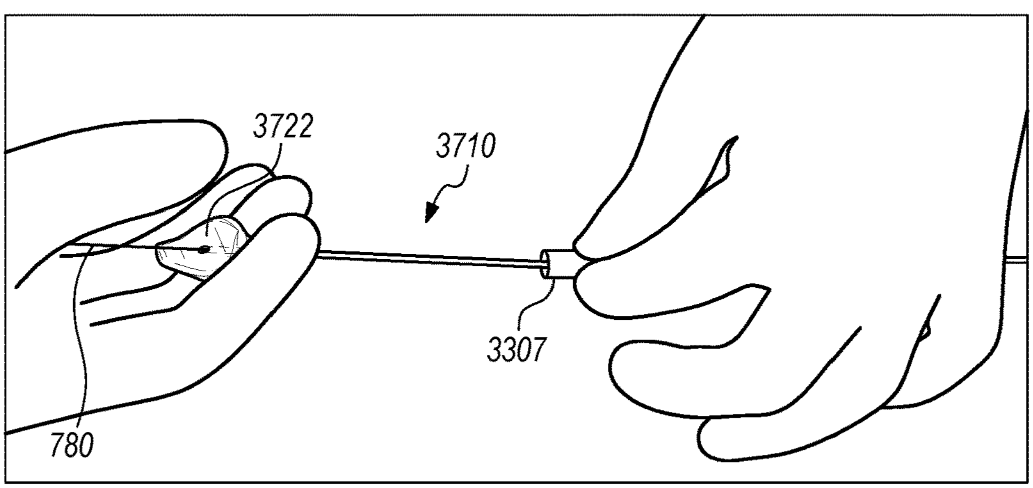


FIG. 14F

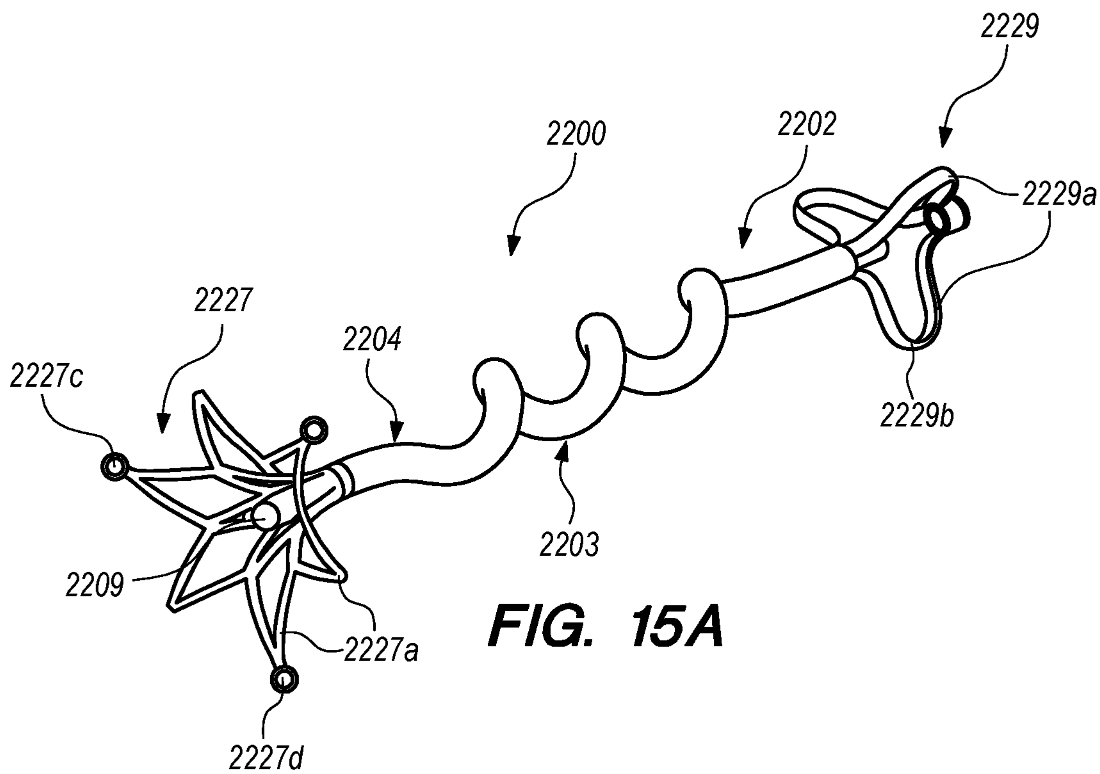


FIG. 15A

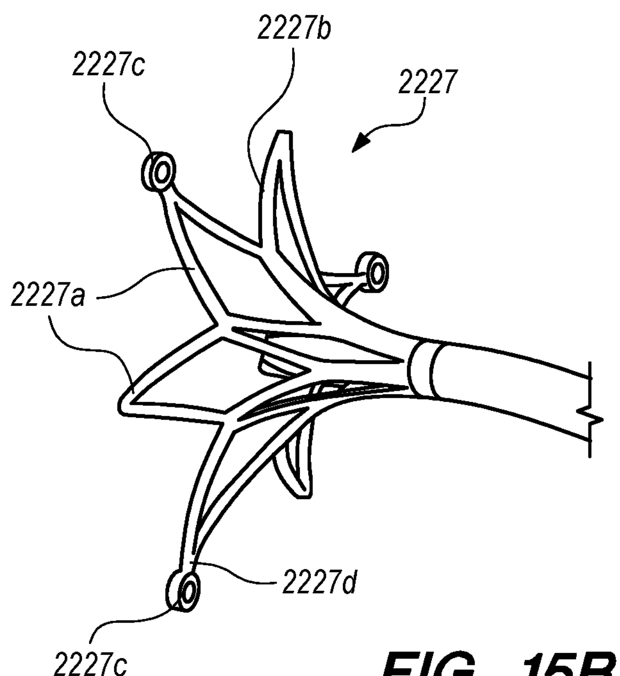


FIG. 15B

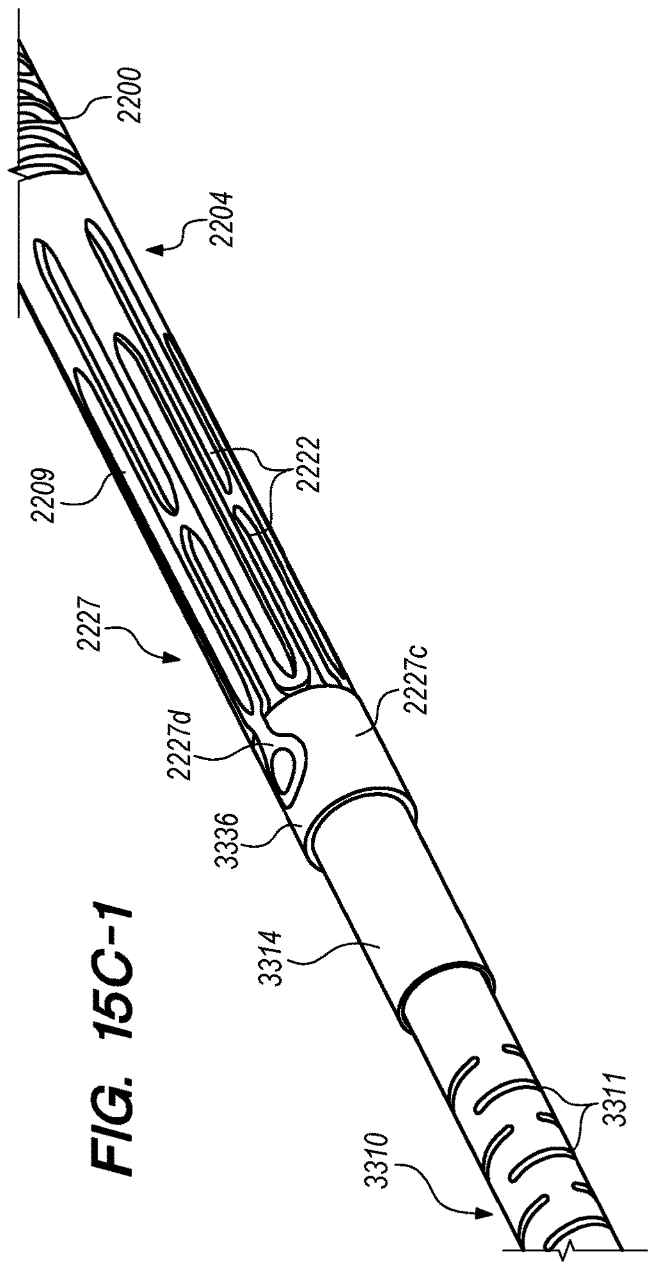


FIG. 15C-1

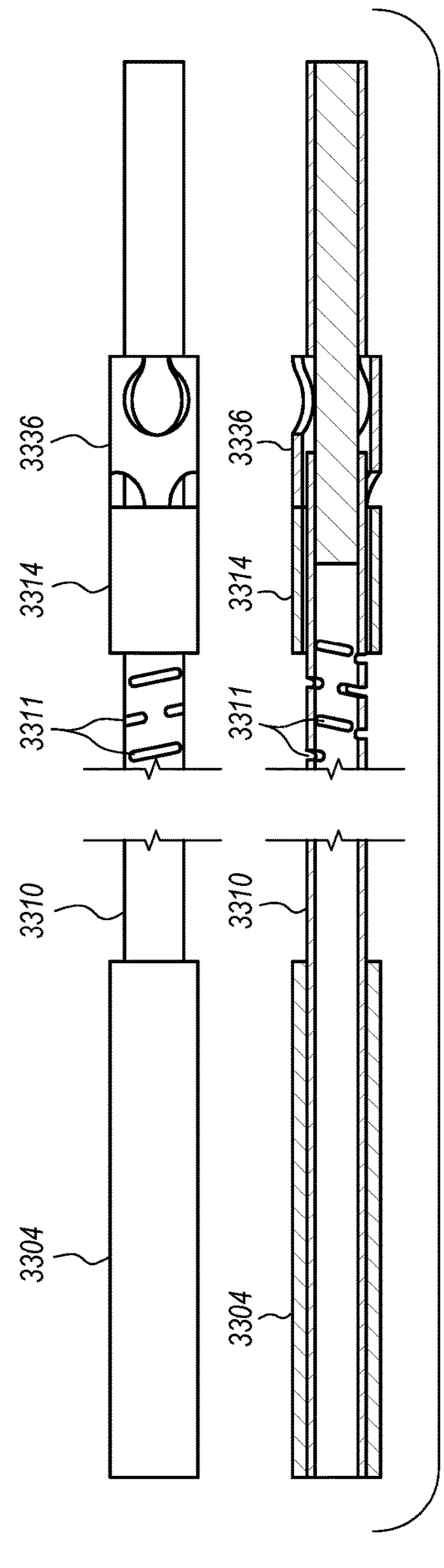


FIG. 15C-2

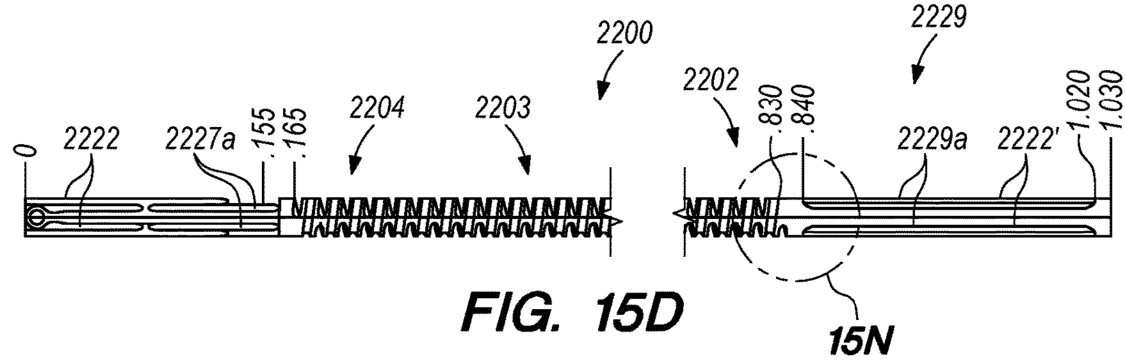


FIG. 15D

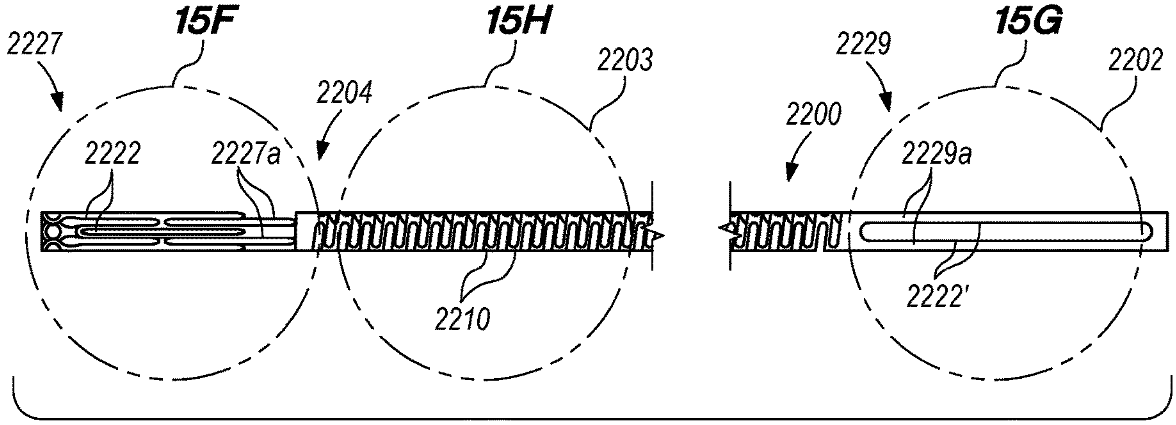


FIG. 15E

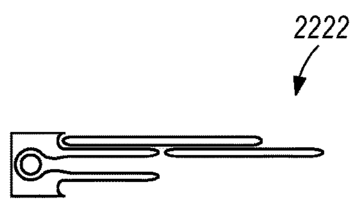


FIG. 15F

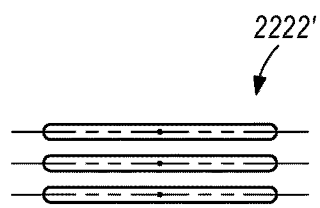


FIG. 15G

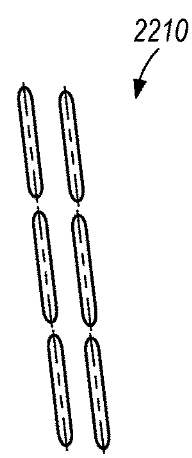


FIG. 15H

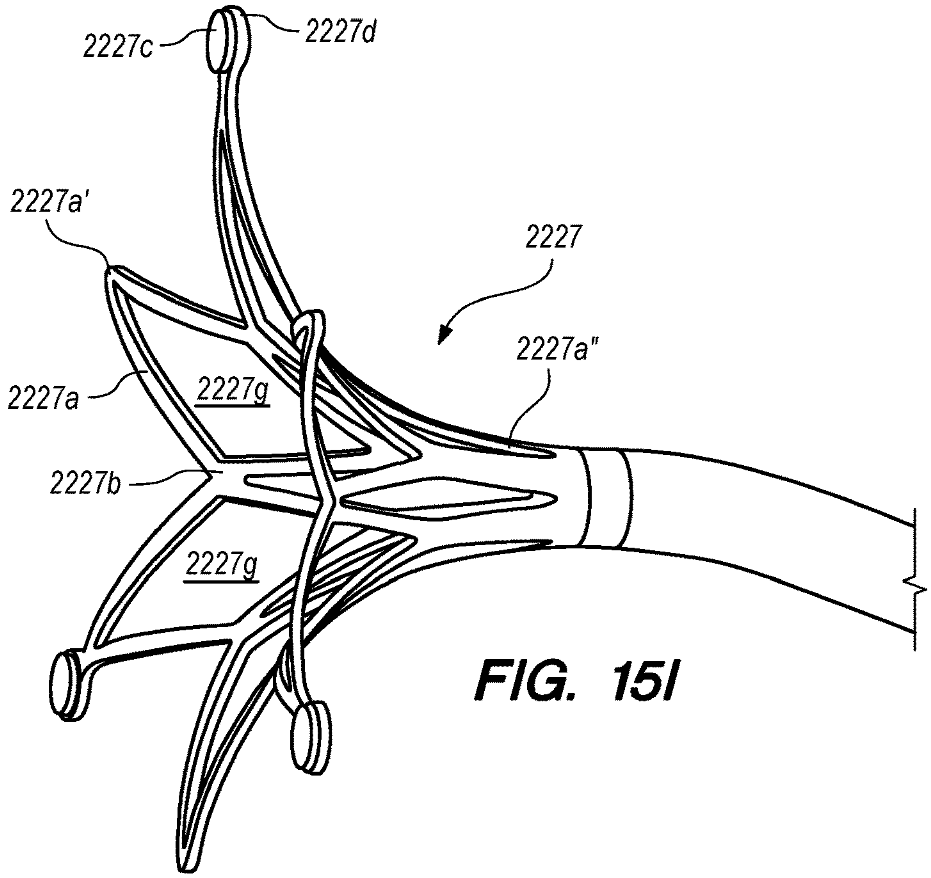


FIG. 15I

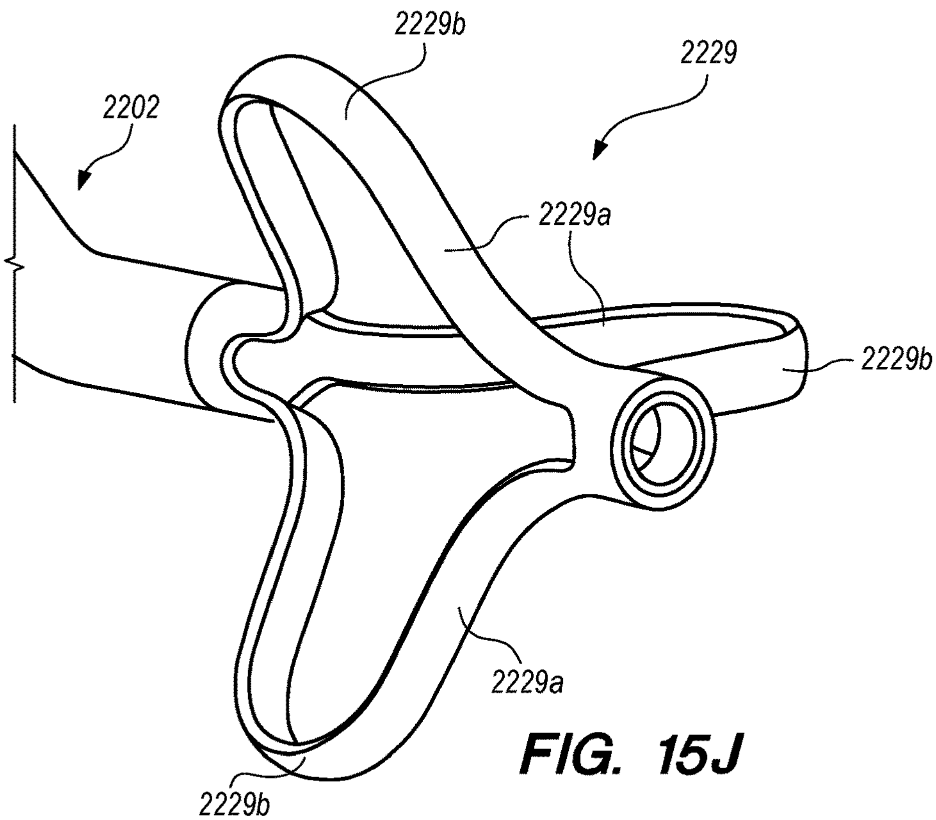


FIG. 15J

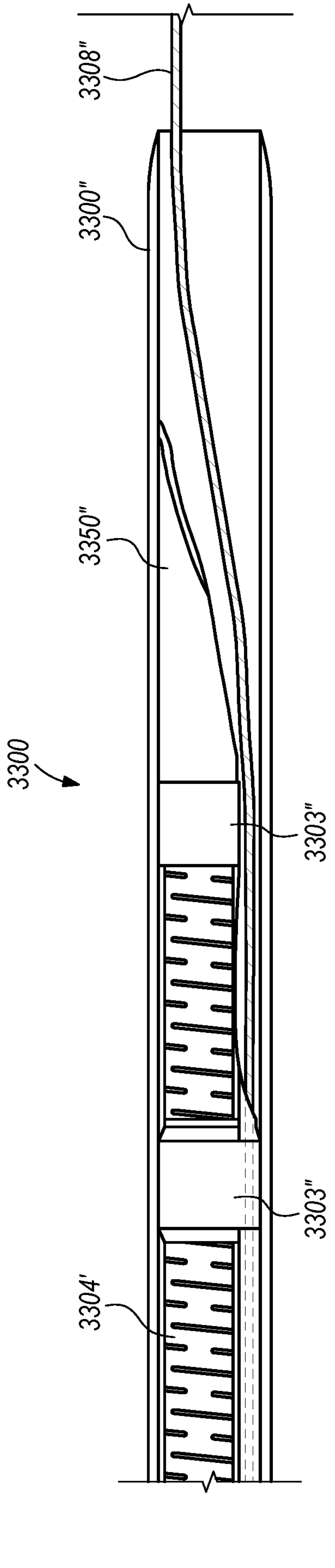


FIG. 16

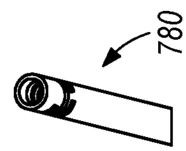


FIG. 17B

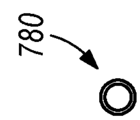


FIG. 17C

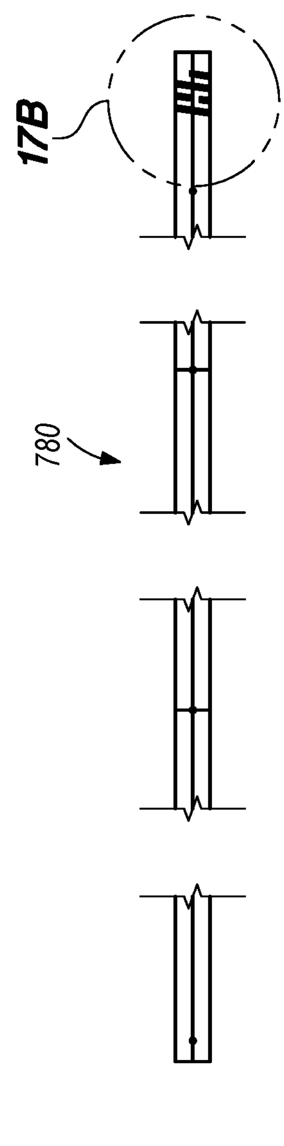


FIG. 17A

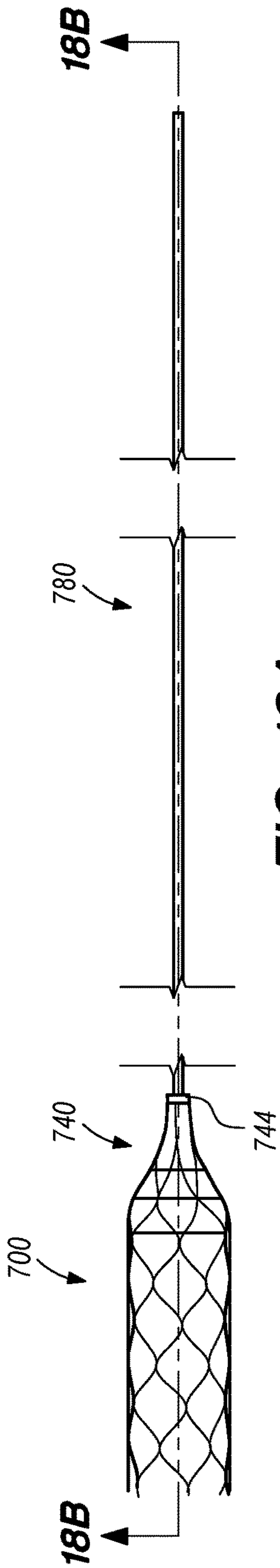


FIG. 18A

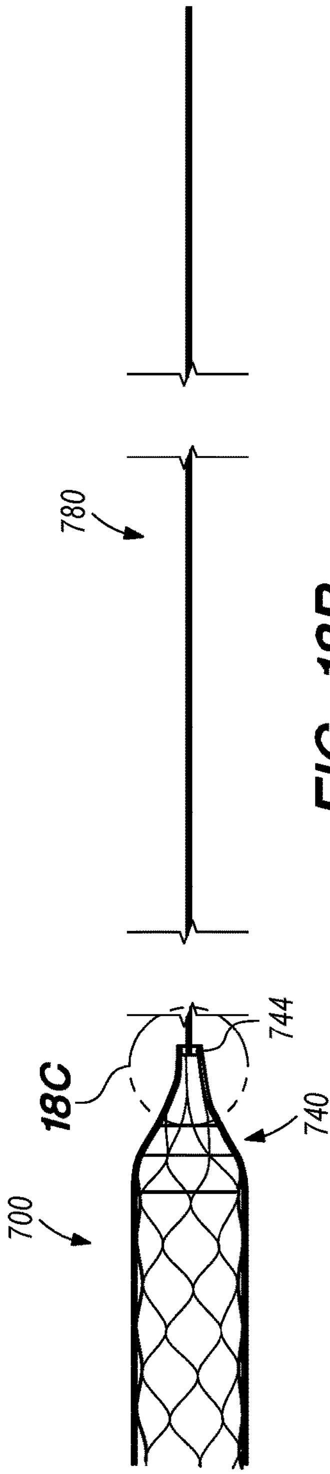


FIG. 18B

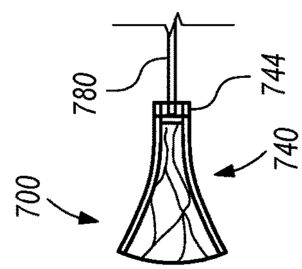


FIG. 18C

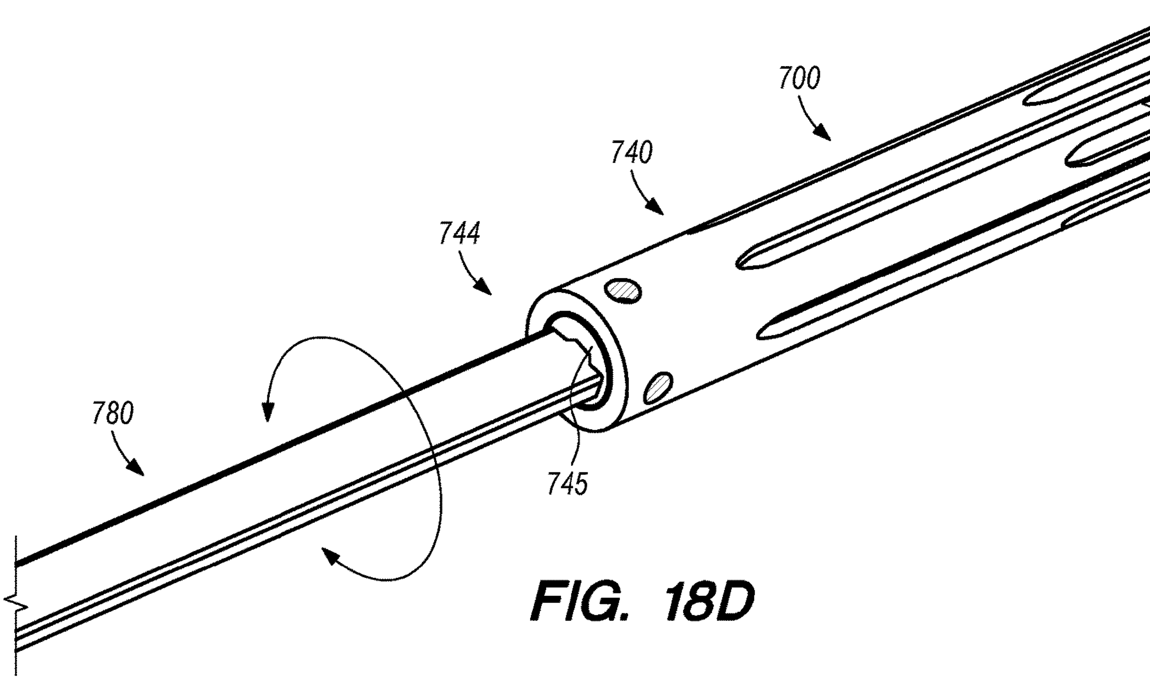


FIG. 18D

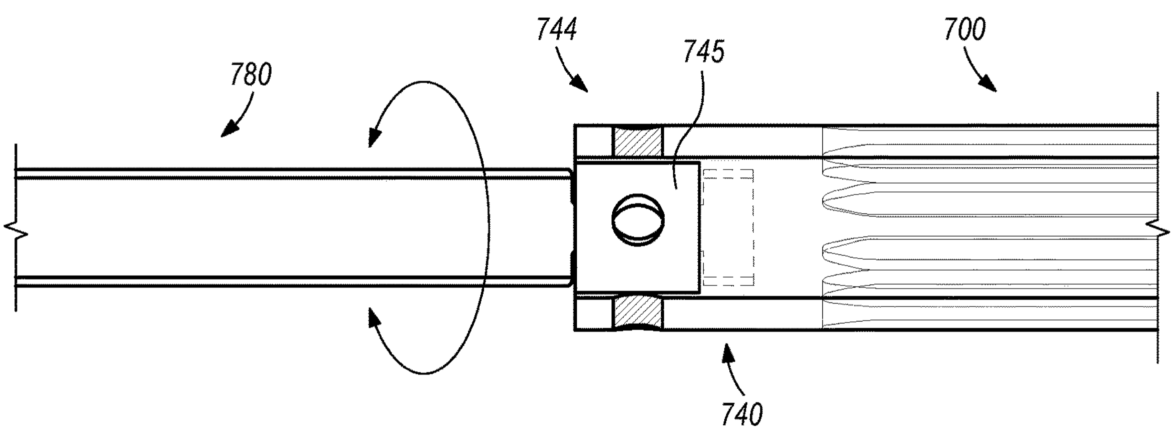


FIG. 18E

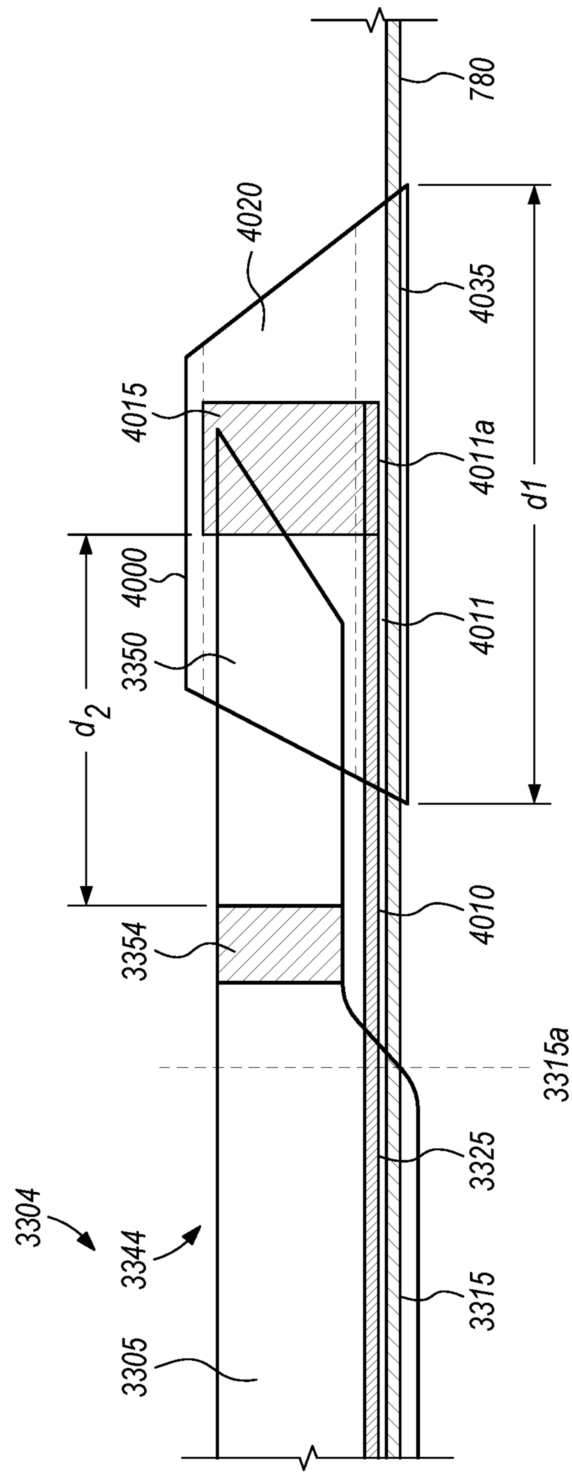

780
4020
4035
4015
4011a
d1
4000
3350
d_2
4011
4010
3354
3315a
3325
3304
3344
3315
3305

FIG. 19A

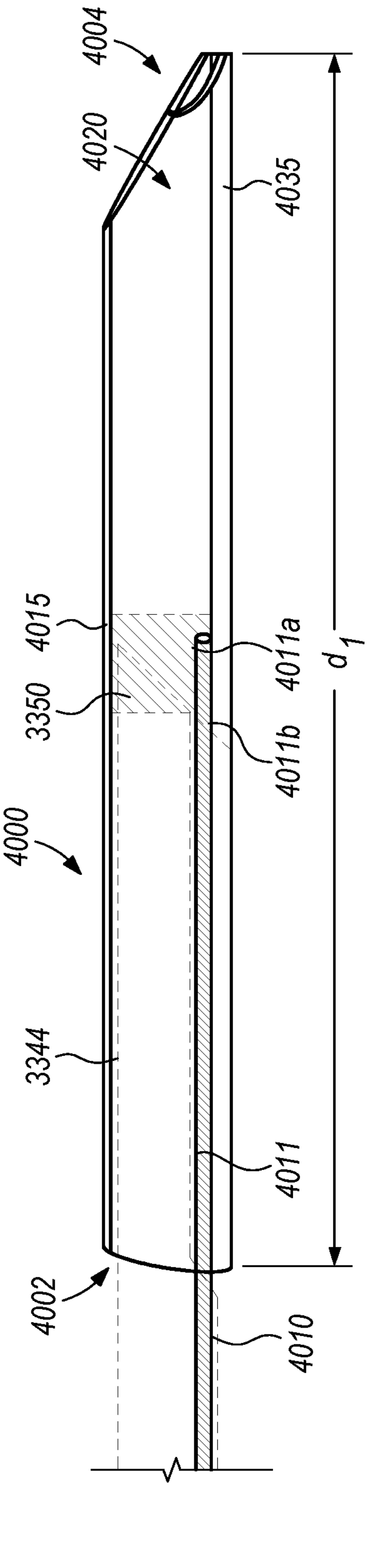


FIG. 19B

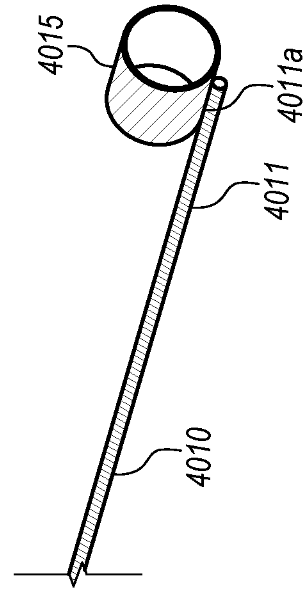


FIG. 19D

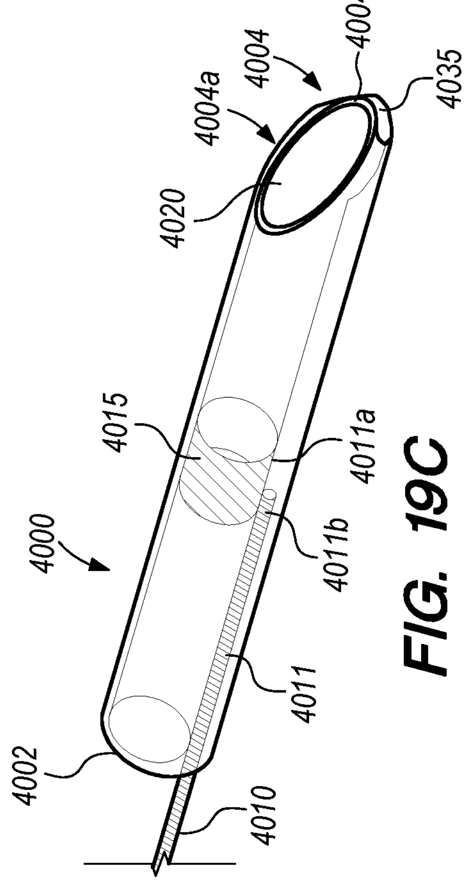


FIG. 19C

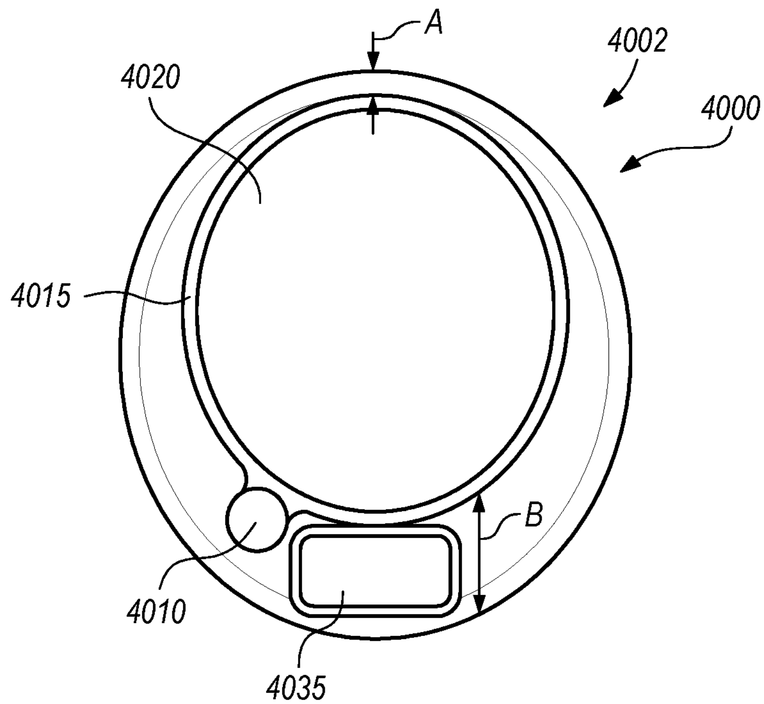


FIG. 19E

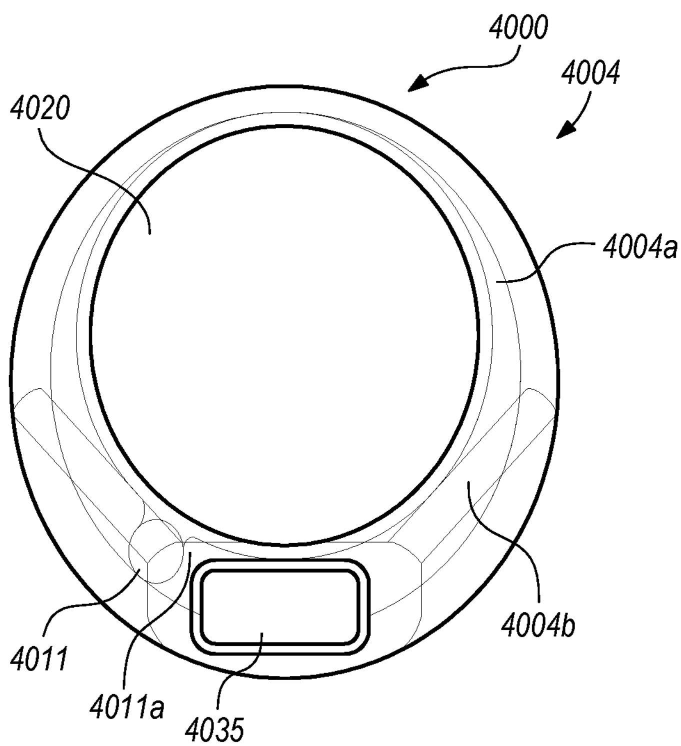


FIG. 19F

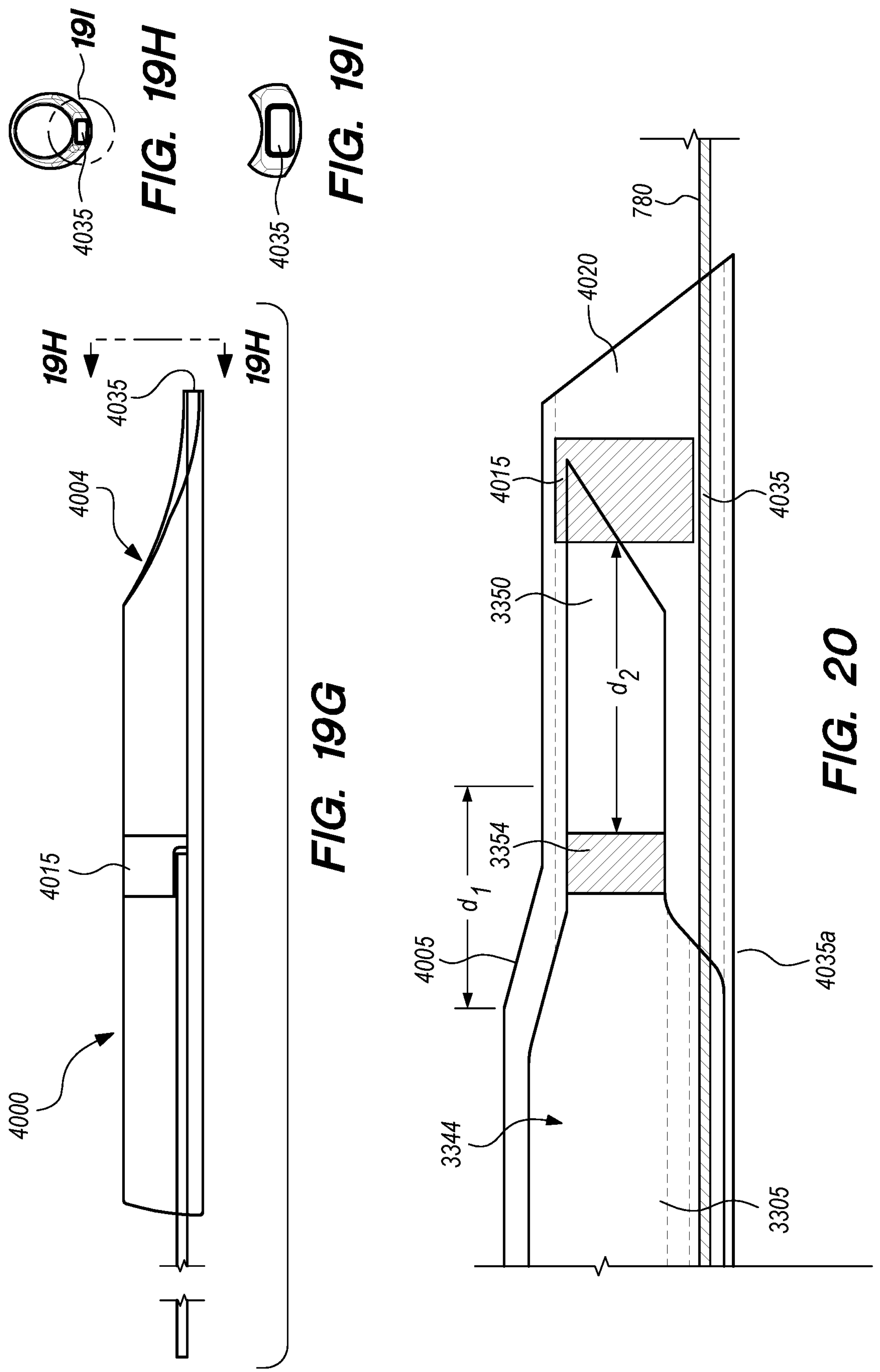


FIG. 19H

FIG. 19I

FIG. 19G

FIG. 20

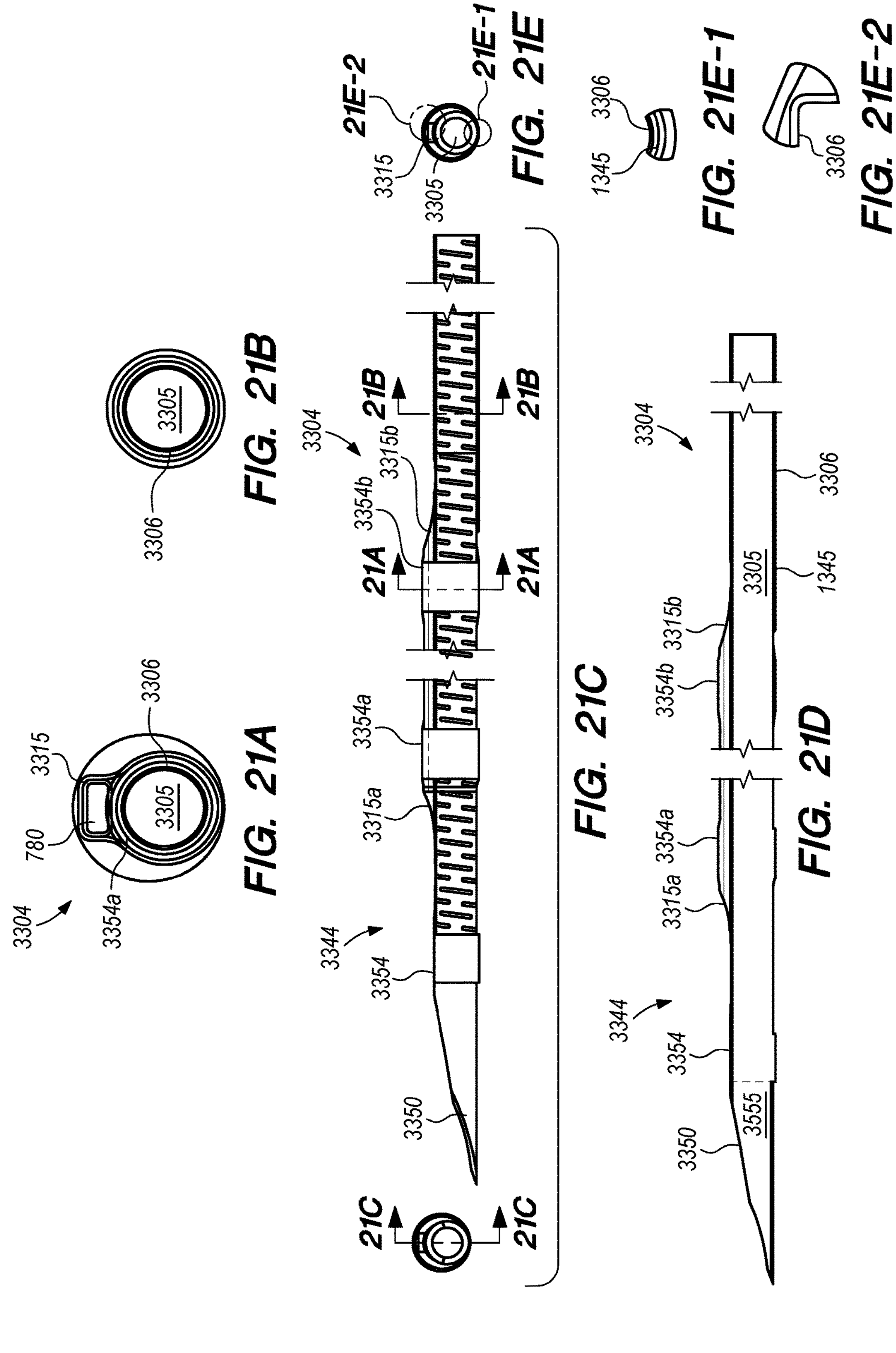


FIG. 21A

FIG. 21B

FIG. 21C

FIG. 21D

FIG. 21E

FIG. 21E-1

FIG. 21E-2

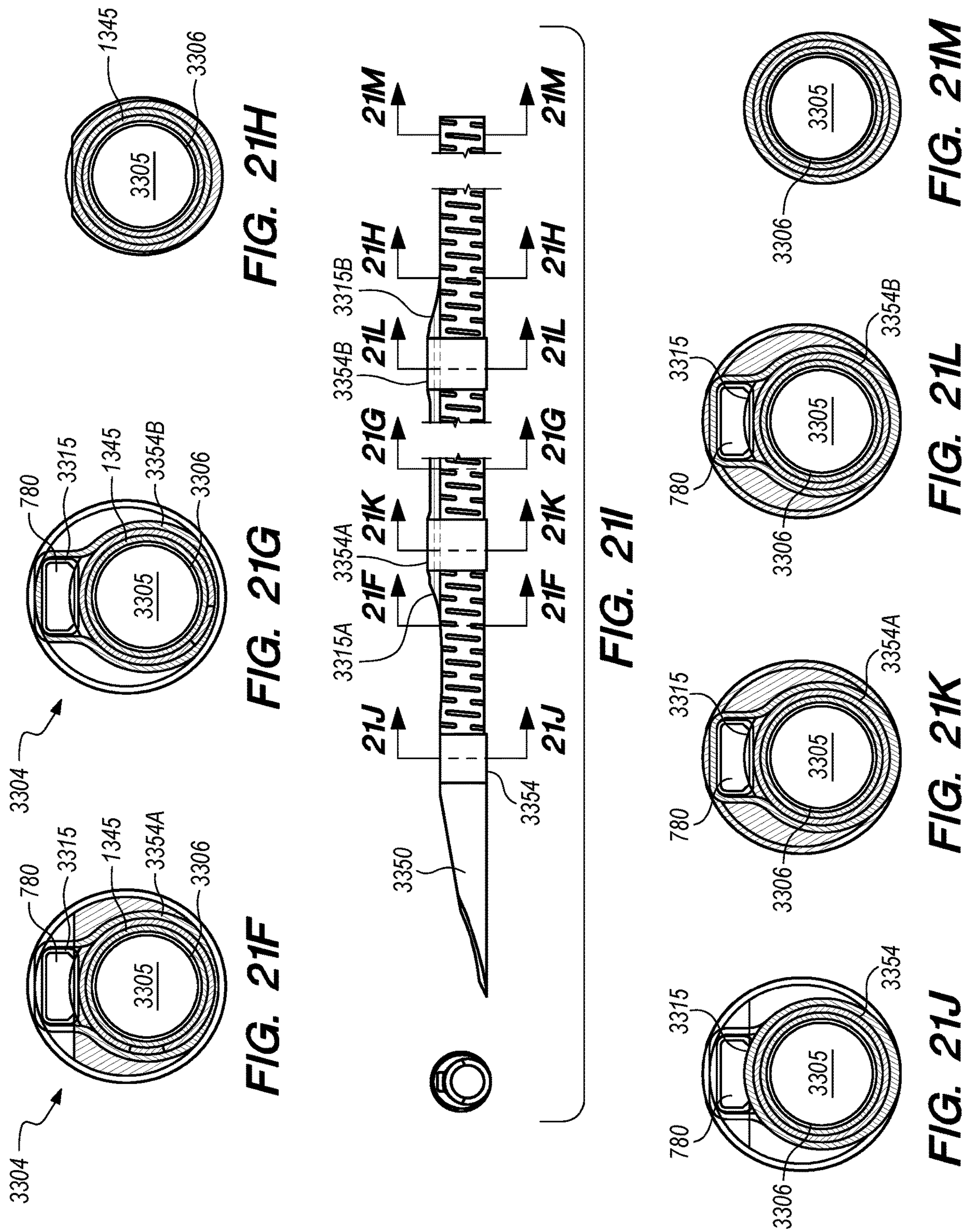


FIG. 21F

FIG. 21G

FIG. 21H

FIG. 21I

FIG. 21J

FIG. 21K

FIG. 21L

FIG. 21M

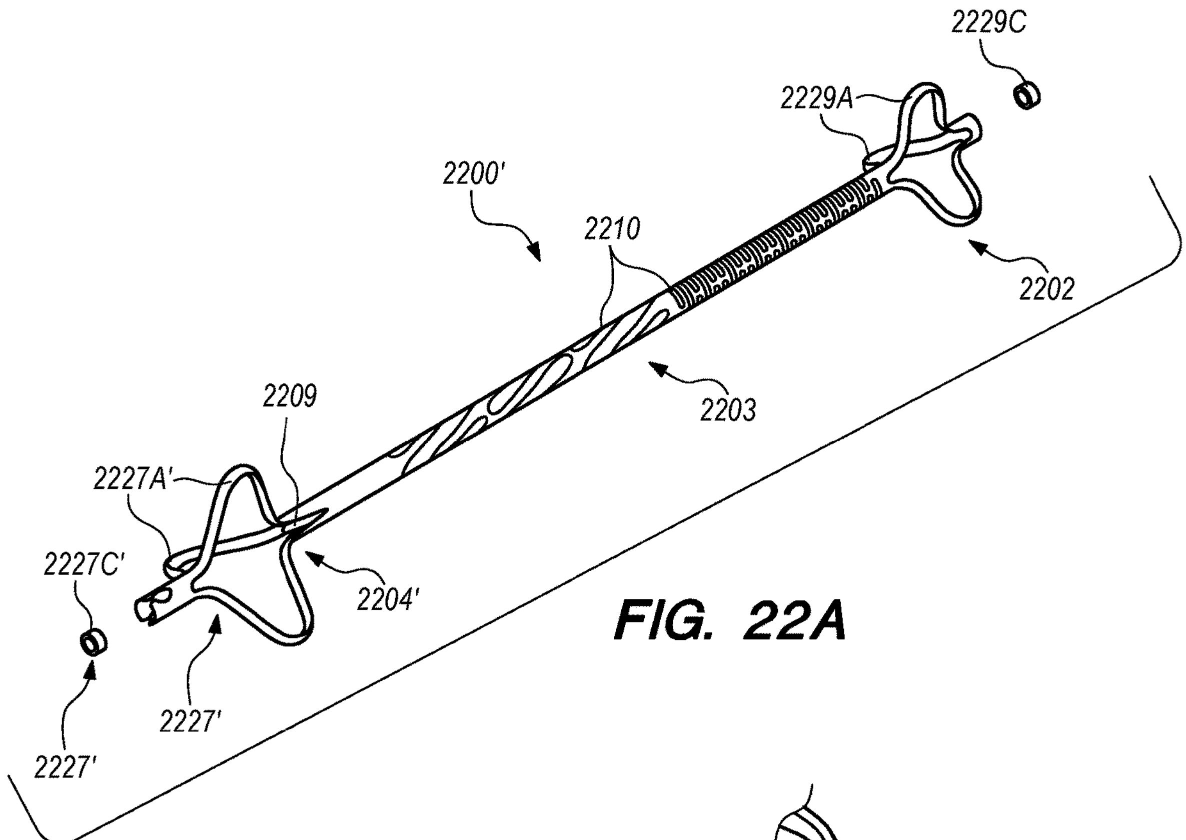


FIG. 22A

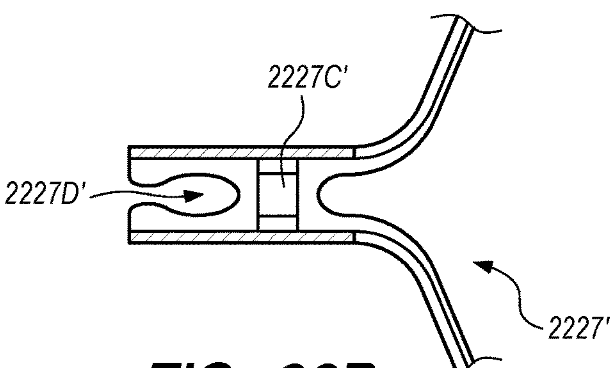


FIG. 22B

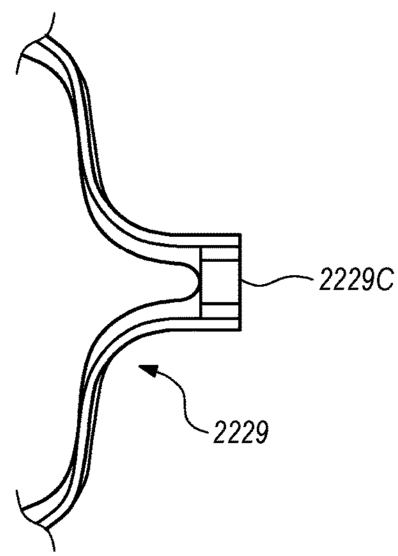


FIG. 22C

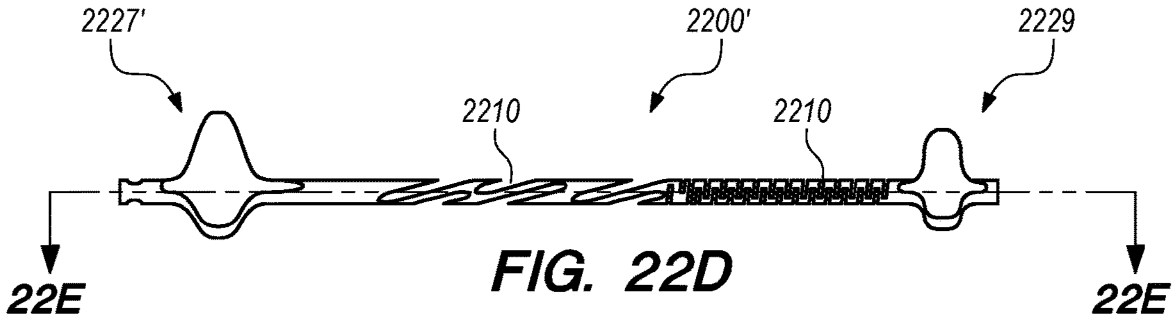


FIG. 22D

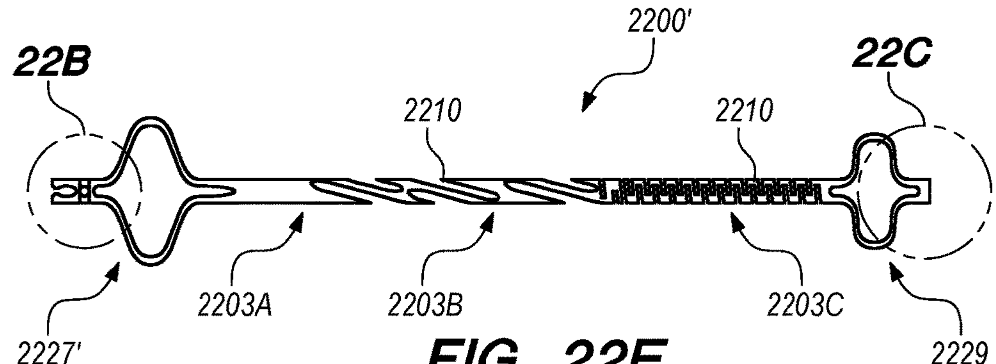


FIG. 22E

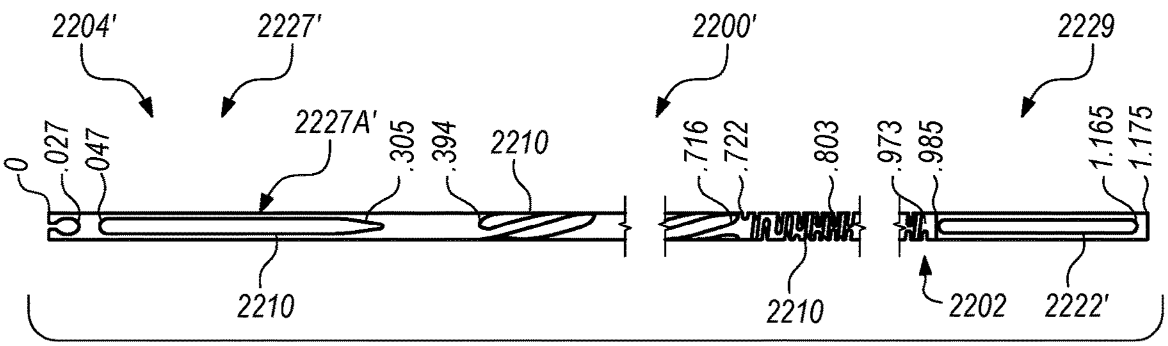


FIG. 22F

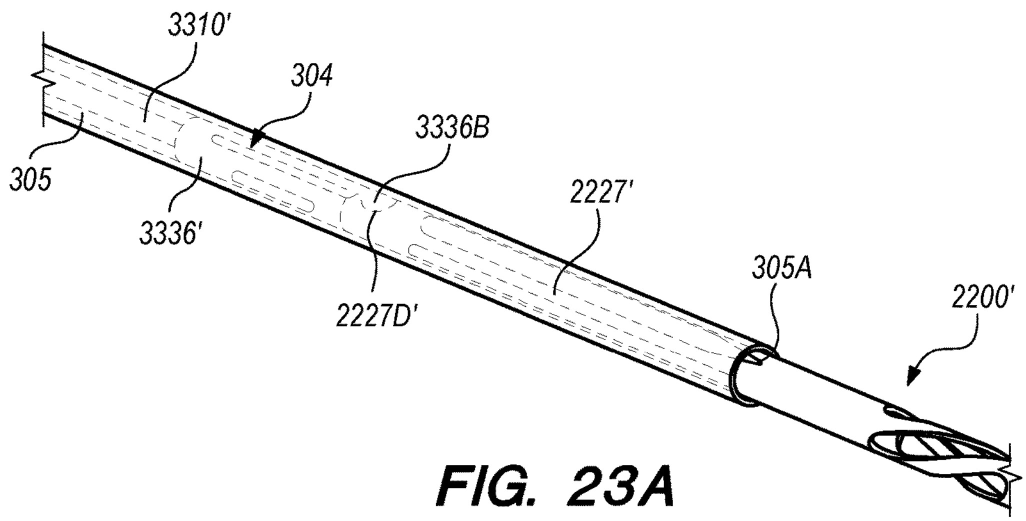


FIG. 23A

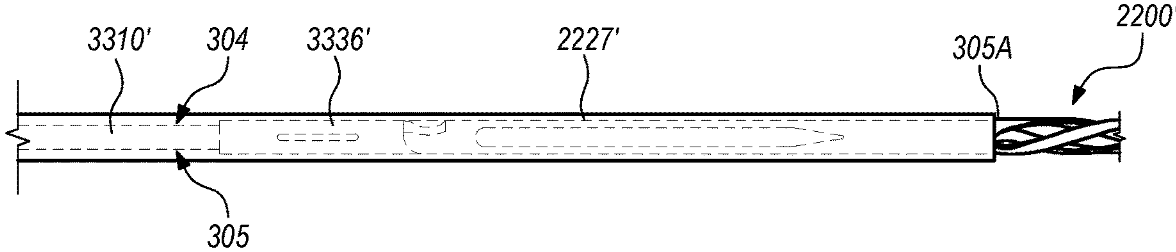


FIG. 23B

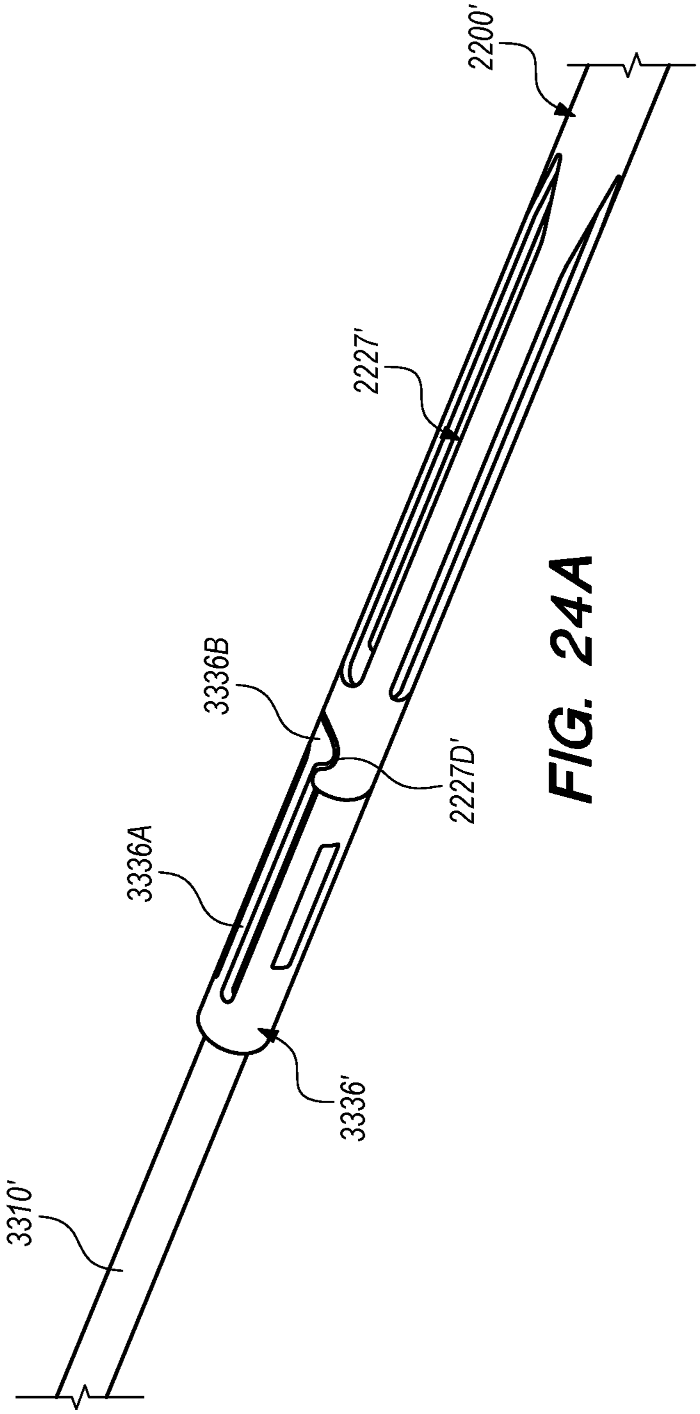


FIG. 24A

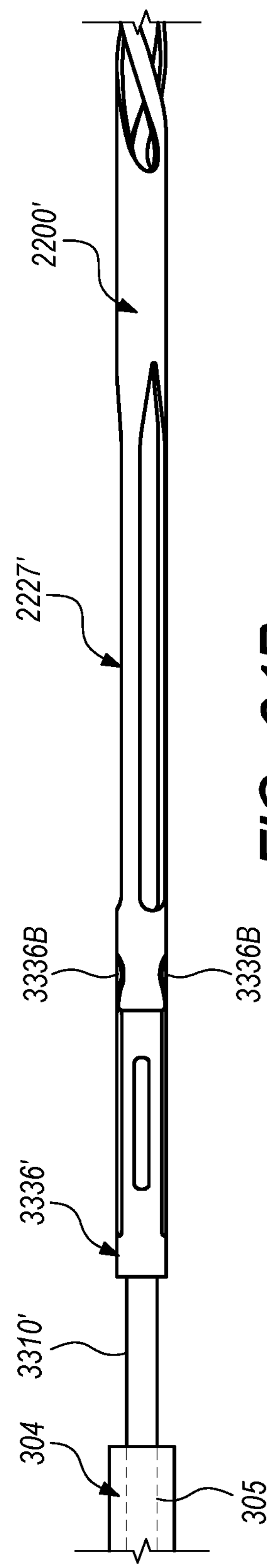


FIG. 24B

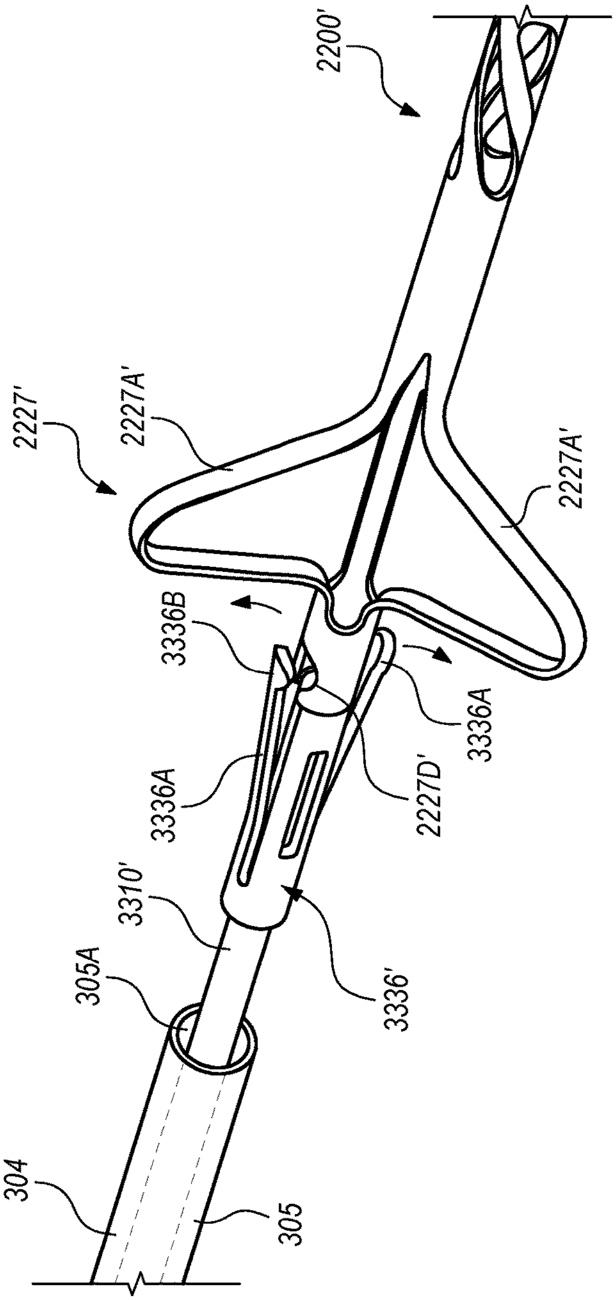


FIG. 24C

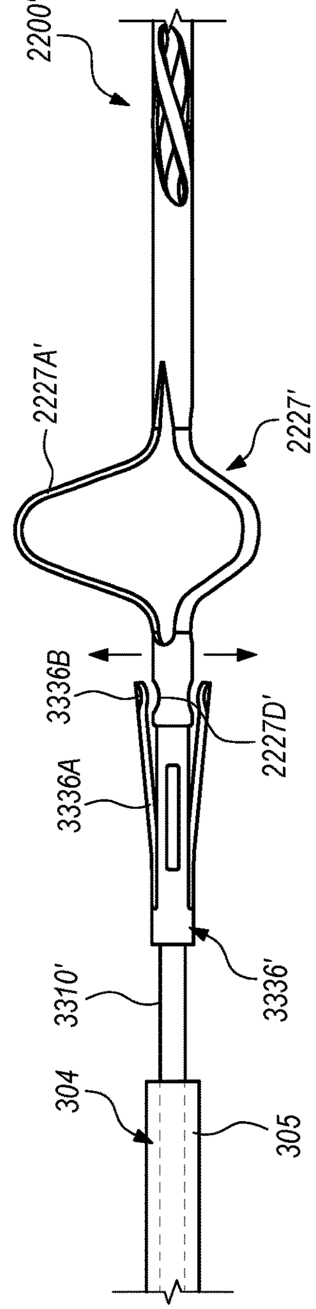


FIG. 24D

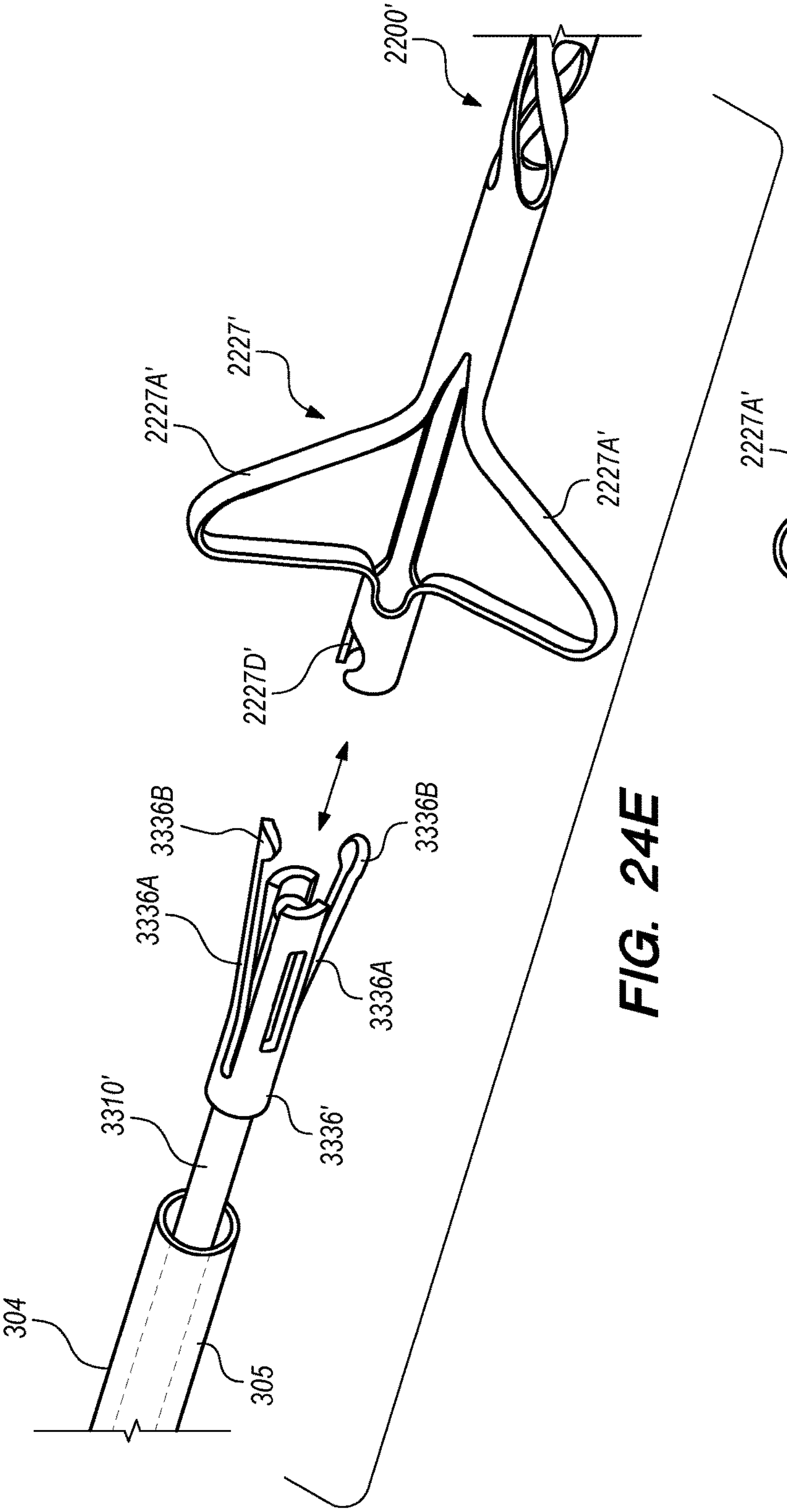


FIG. 24E

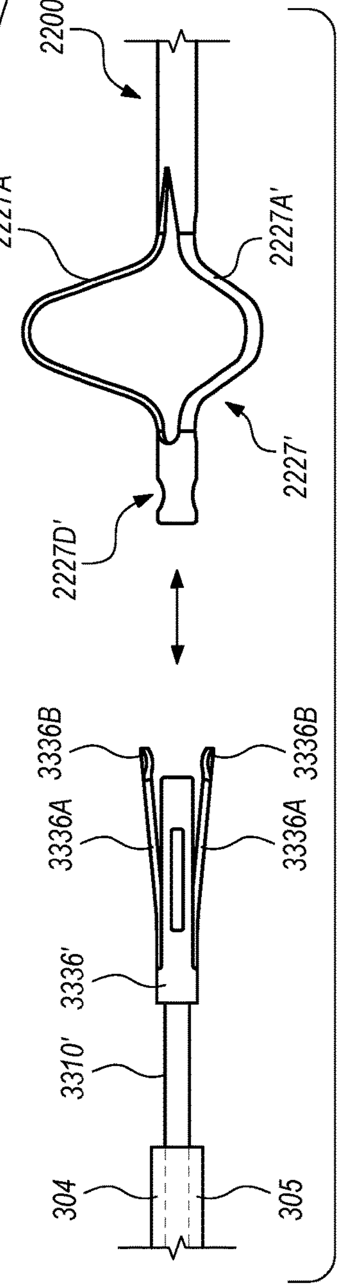


FIG. 24F

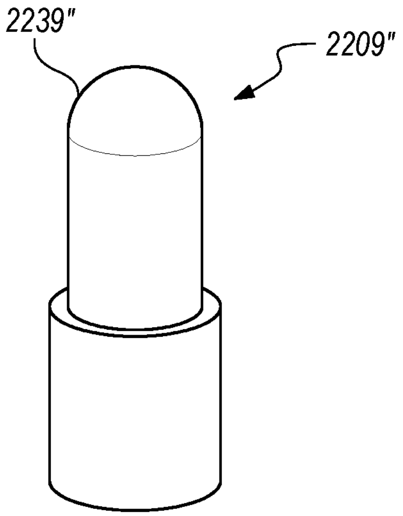


FIG. 25A

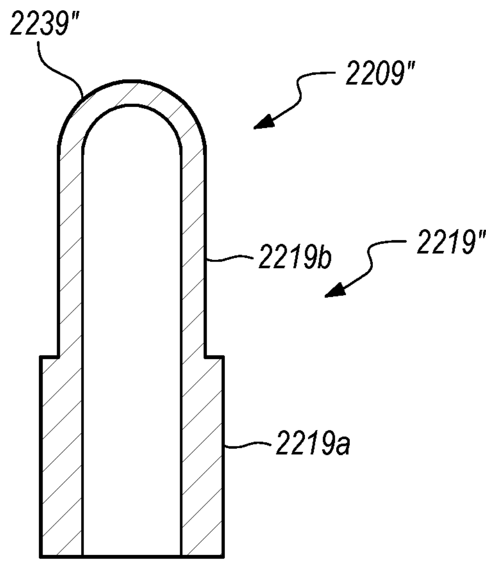


FIG. 25B

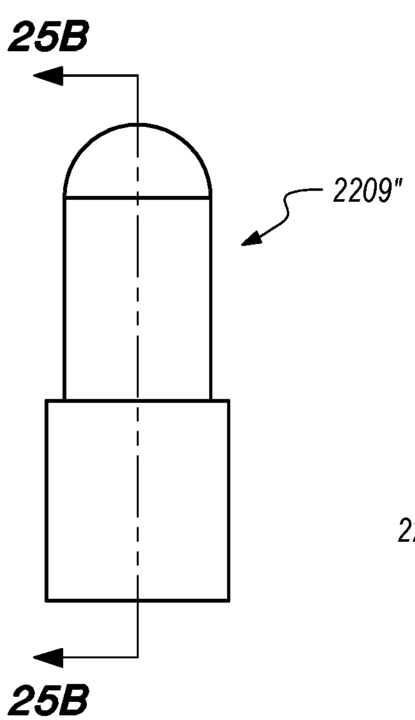


FIG. 25C

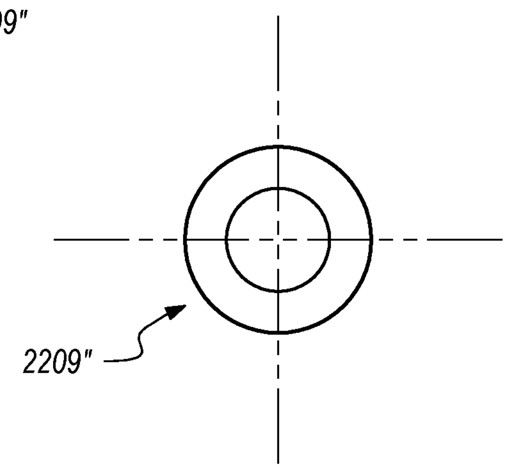


FIG. 25D

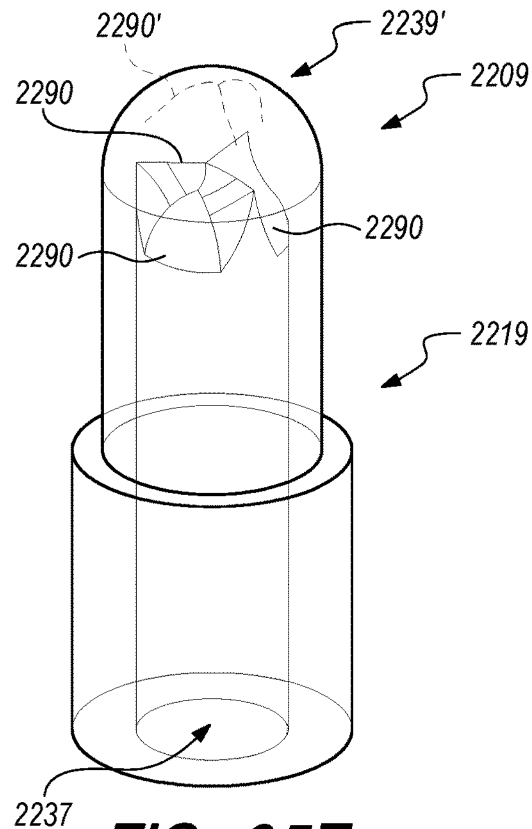


FIG. 25E

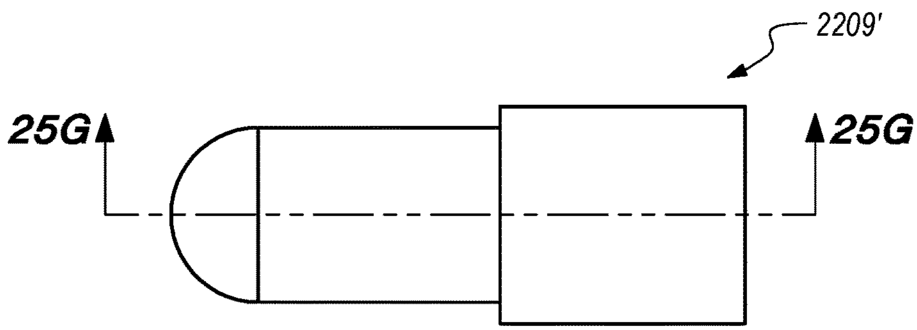


FIG. 25F

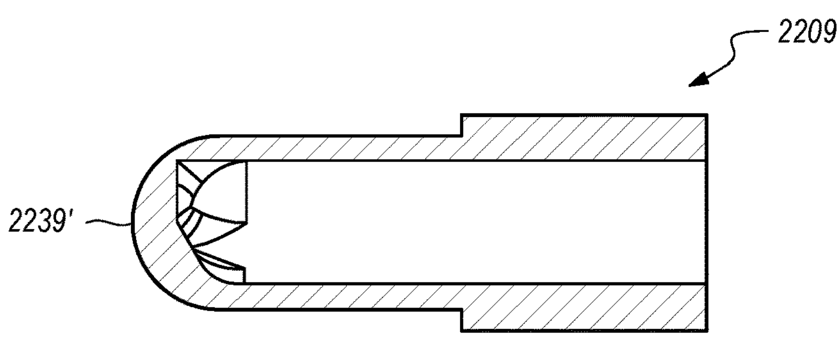


FIG. 25G

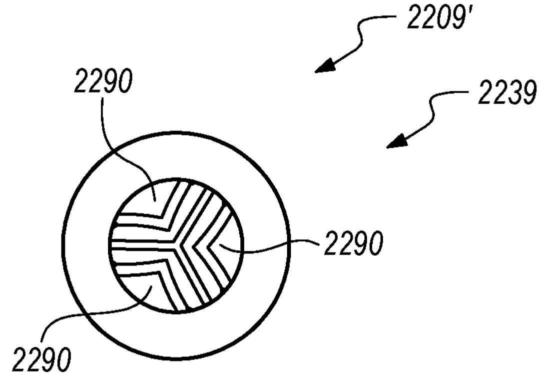


FIG. 25H

DESIGN TABLE		
DASH NO.	DOME THICKNESS	MIN THICKNESS
-01	0.005	0.001
-02	0.007	0.002
-03	0.009	0.003

FIG. 25I

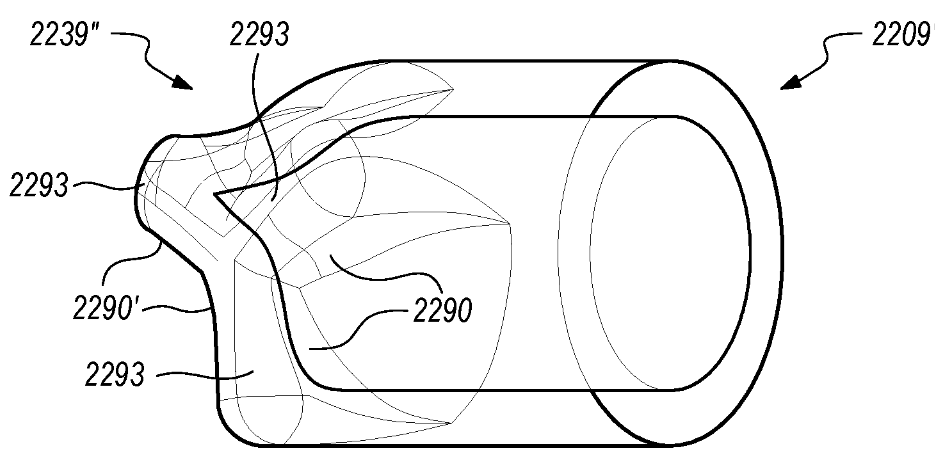


FIG. 25J

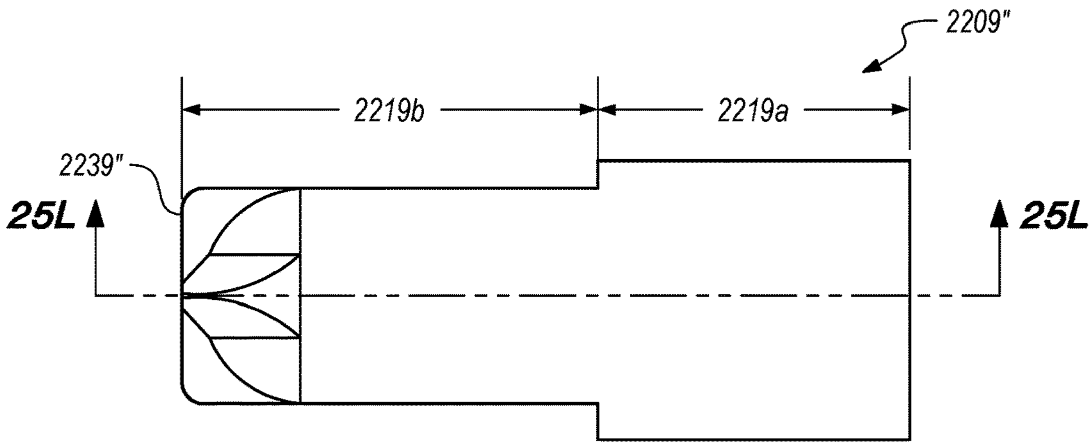


FIG. 25K

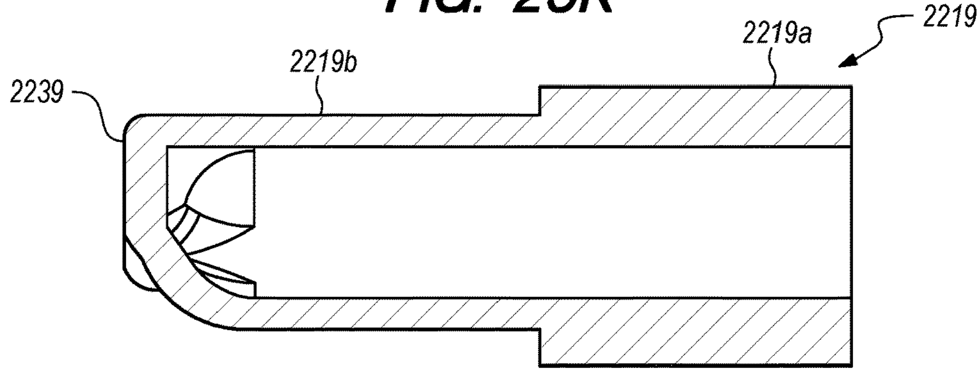


FIG. 25L

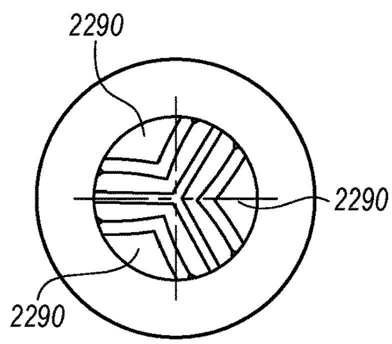


FIG. 25M

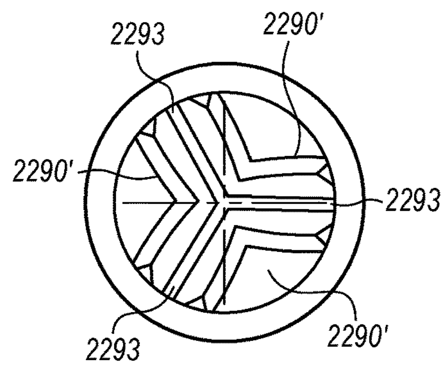


FIG. 25N

DESIGN TABLE	
DASH NO.	DOME THICKNESS
-01	0.002
-02	0.003
-03	0.004

FIG. 25O

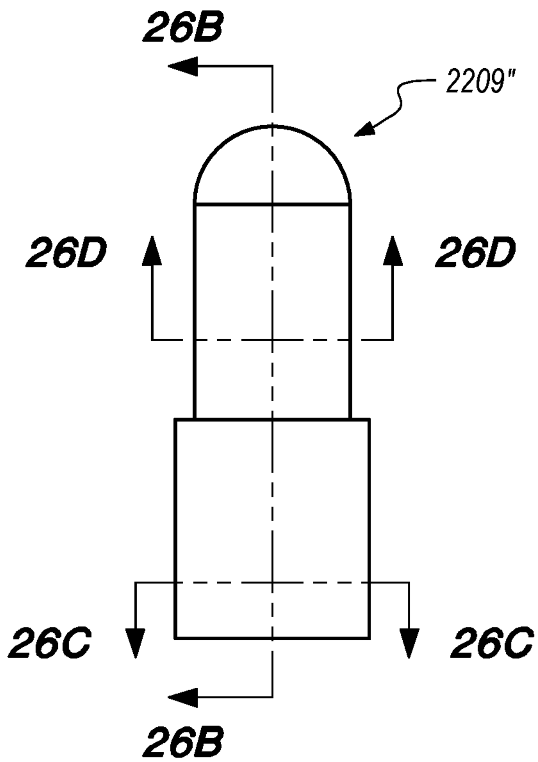


FIG. 26A

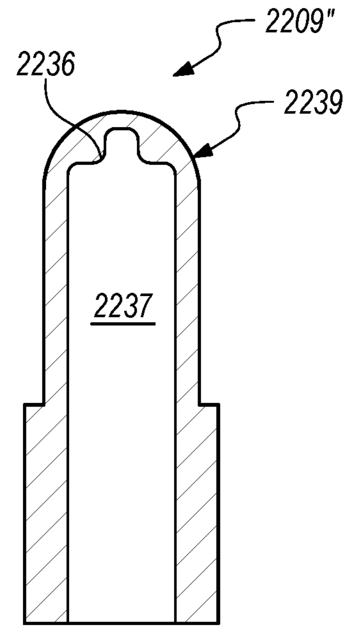


FIG. 26B

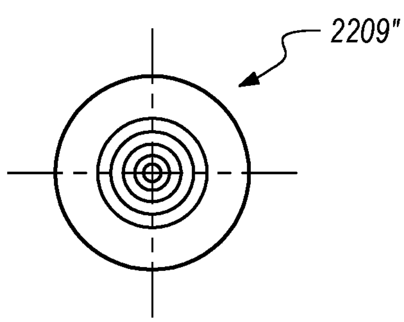


FIG. 26C

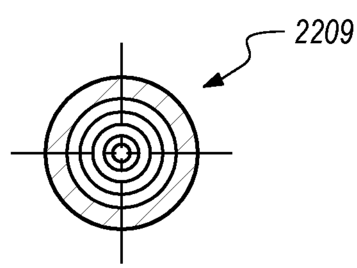


FIG. 26D

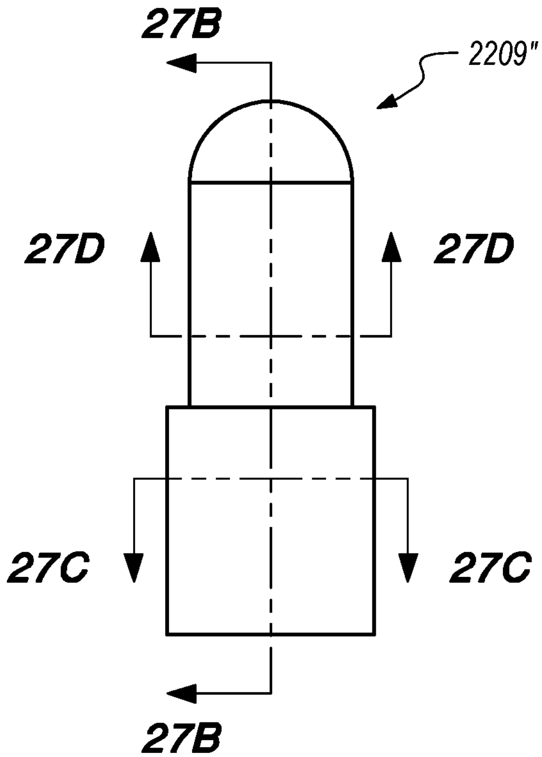


FIG. 27A

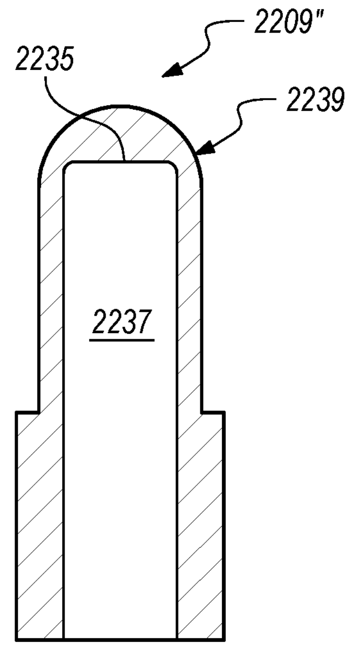


FIG. 27B

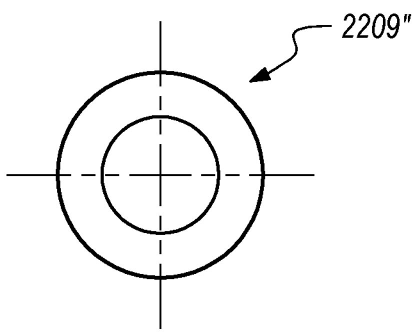


FIG. 27C

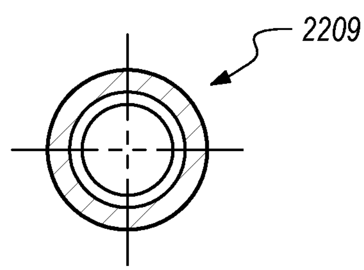


FIG. 27D

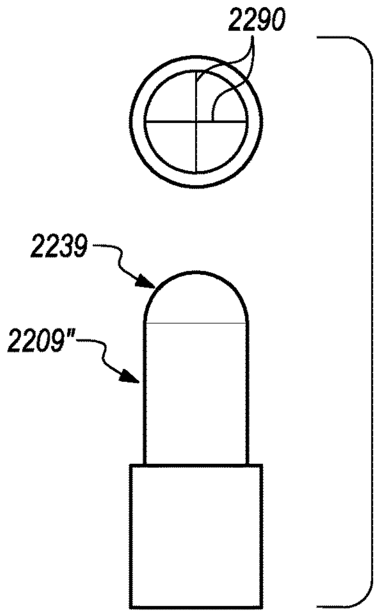


FIG. 28A

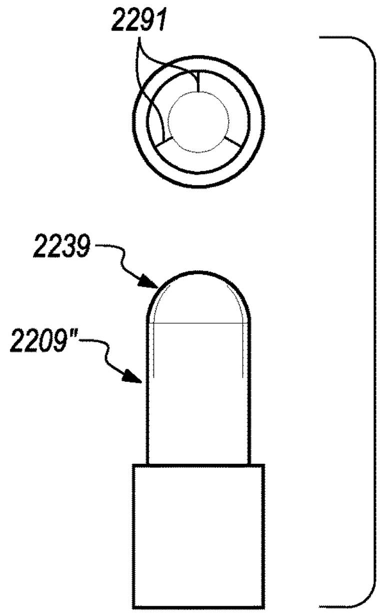


FIG. 28B

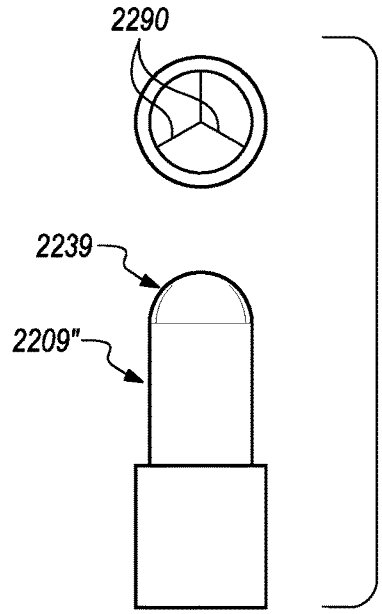


FIG. 28C

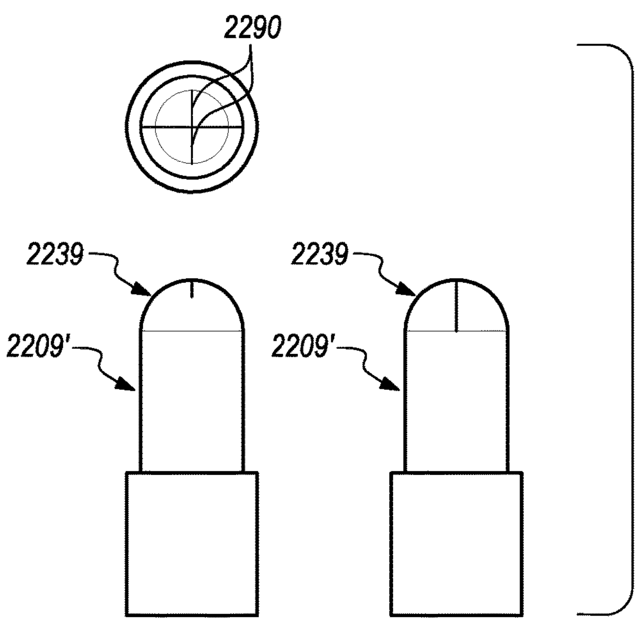


FIG. 28D

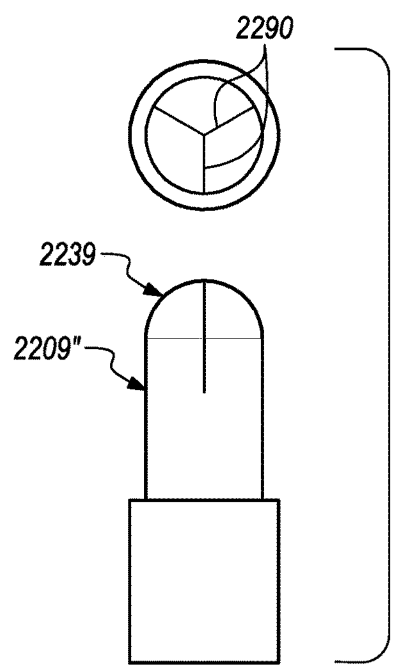


FIG. 28E

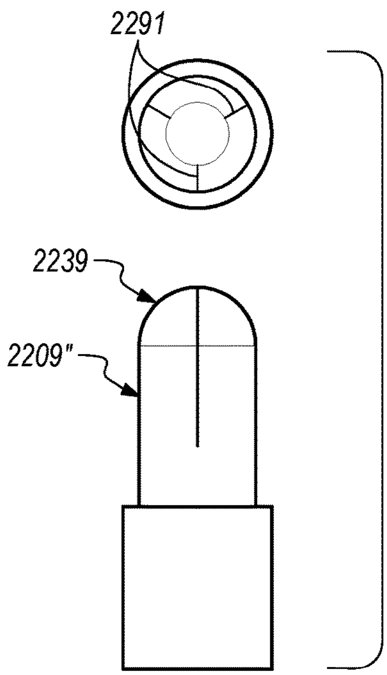


FIG. 28F

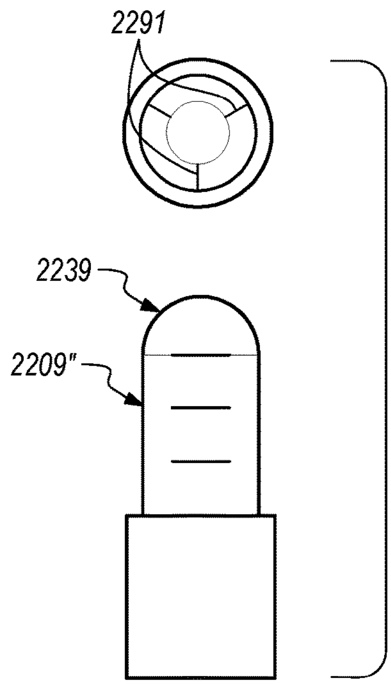


FIG. 28G

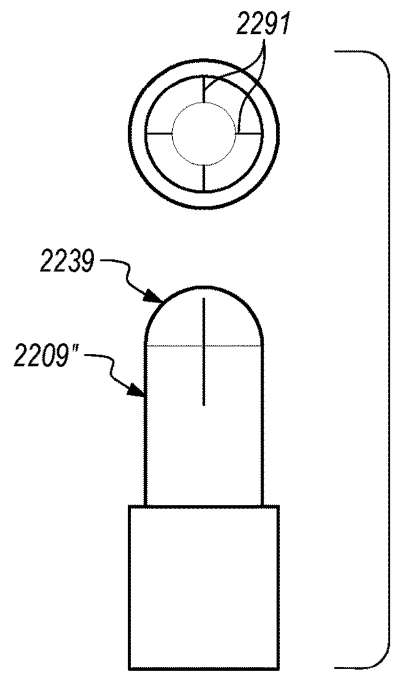


FIG. 28H

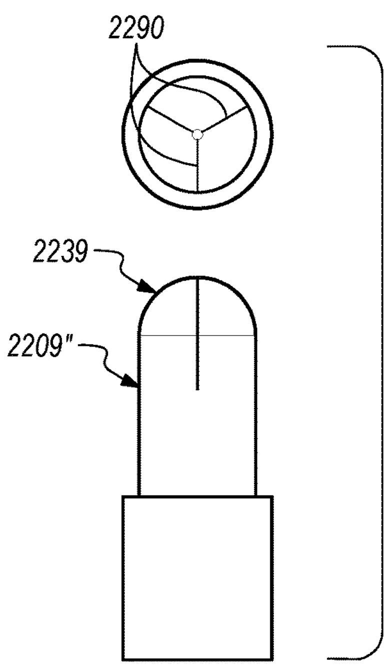


FIG. 28I

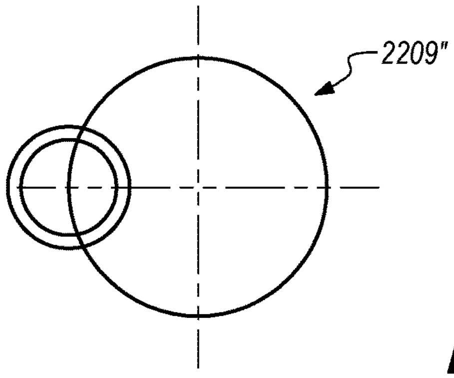


FIG. 28J

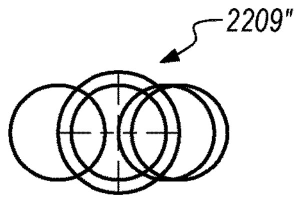


FIG. 28K

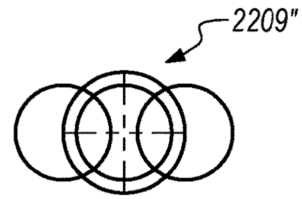


FIG. 28L

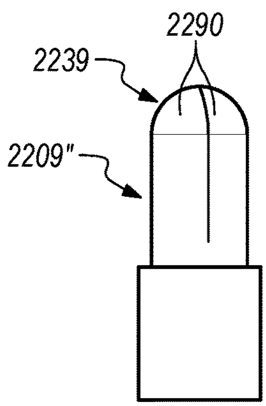


FIG. 28M

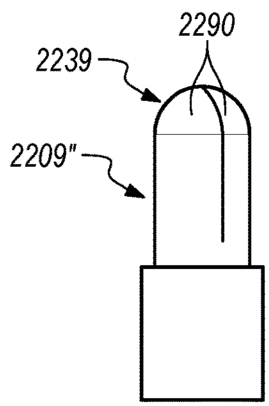


FIG. 28N

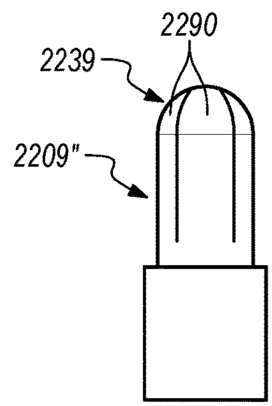


FIG. 28O

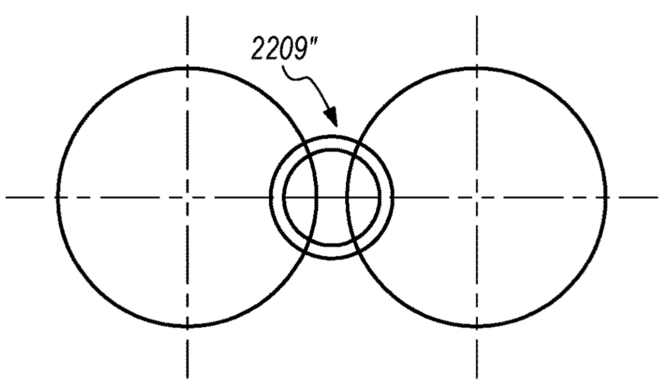


FIG. 28P

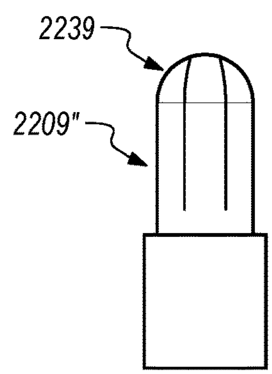


FIG. 28Q

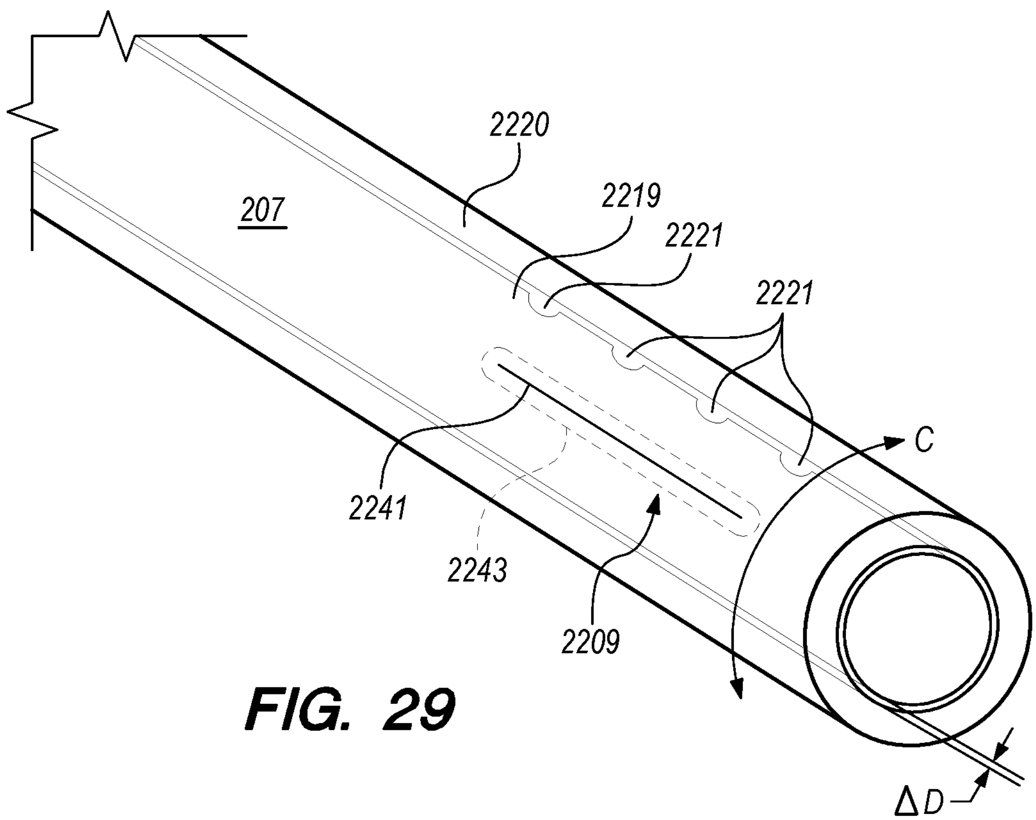


FIG. 29

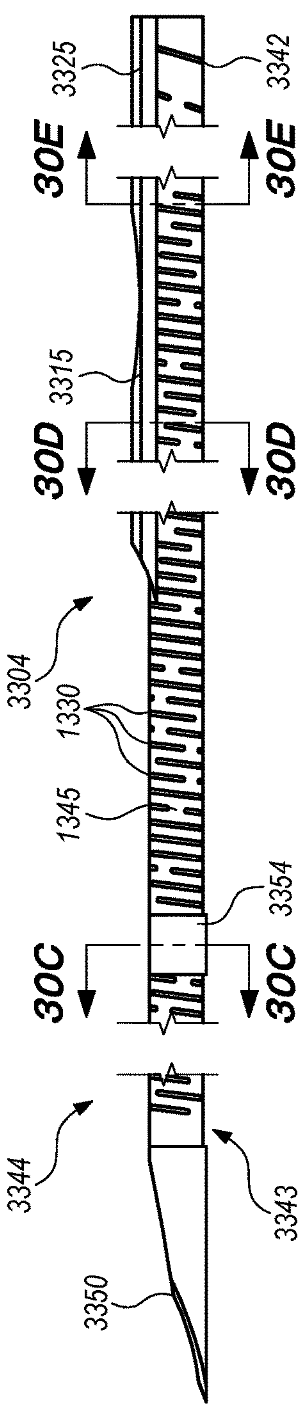


FIG. 30A

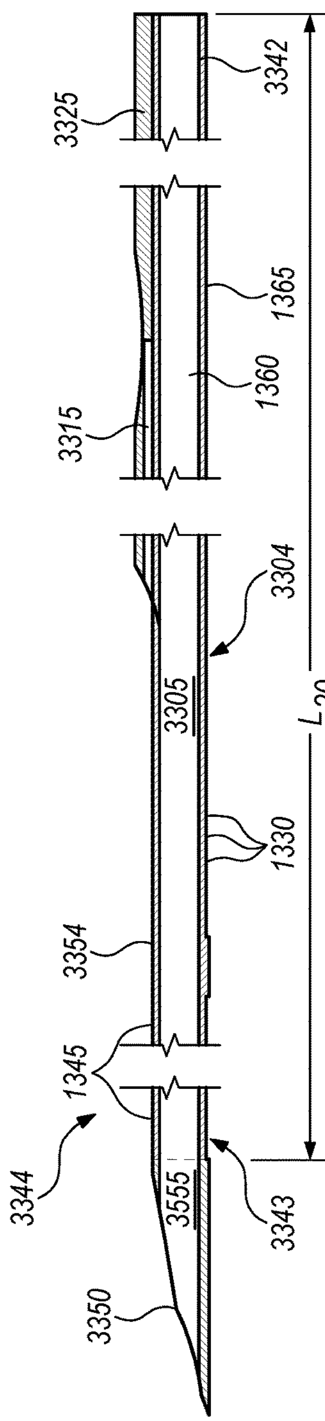


FIG. 30B

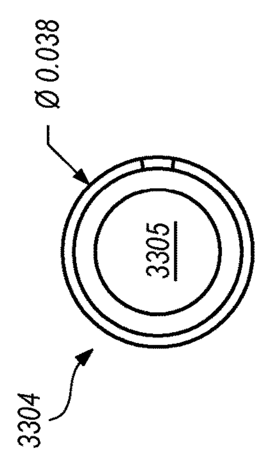


FIG. 30C

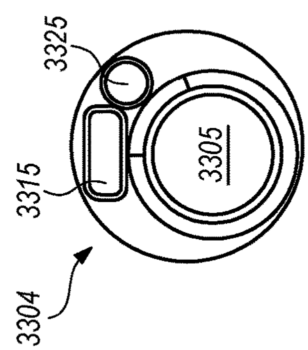


FIG. 30D

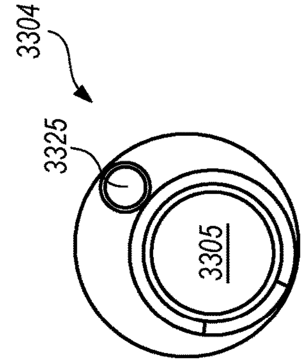


FIG. 30E

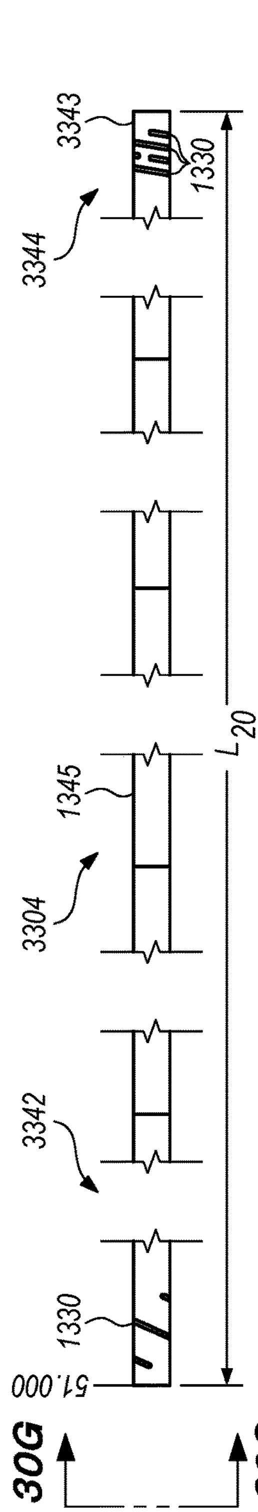


FIG. 30F

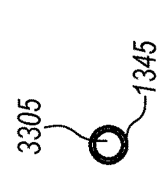


FIG. 30G

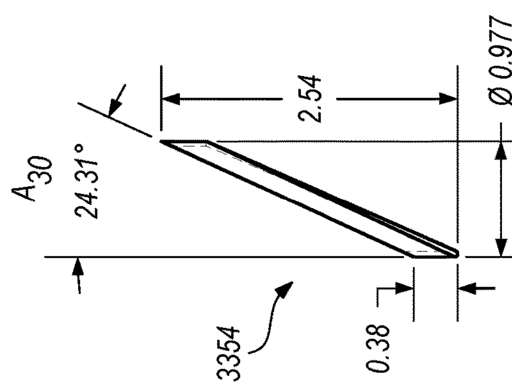


FIG. 31A

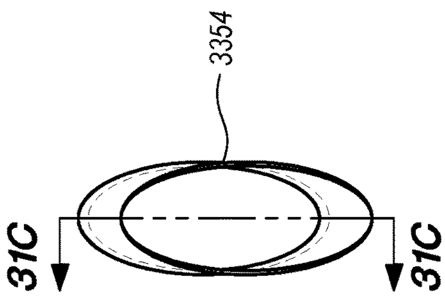


FIG. 31B

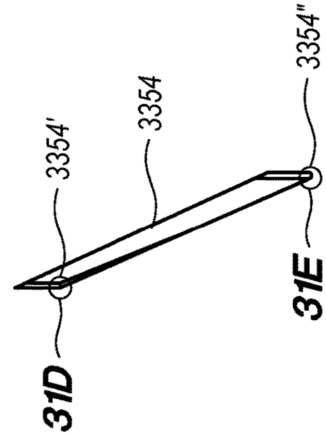


FIG. 31C

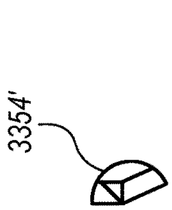


FIG. 31D

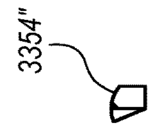


FIG. 31E

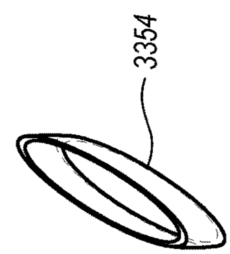


FIG. 31F

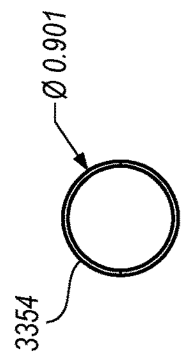


FIG. 31G

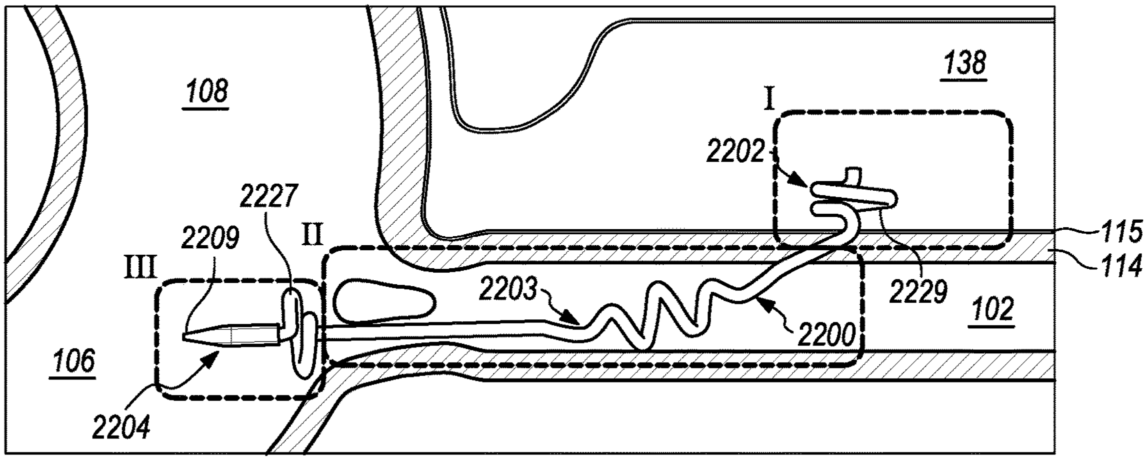


FIG. 32

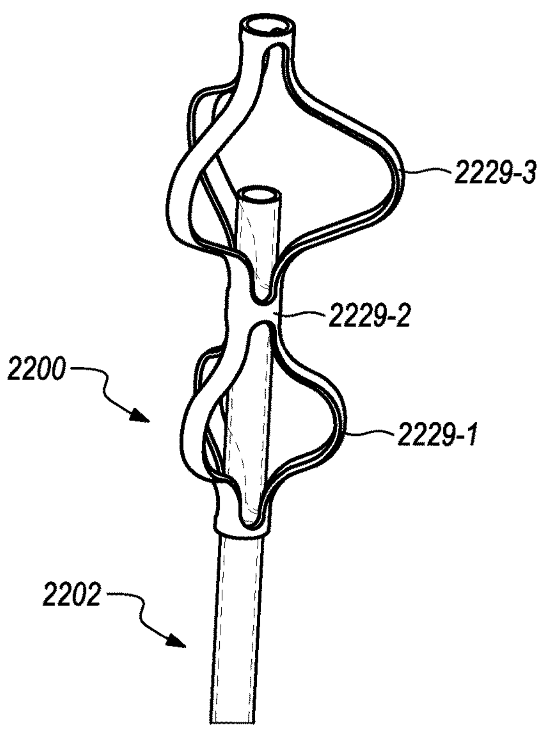


FIG. 33A

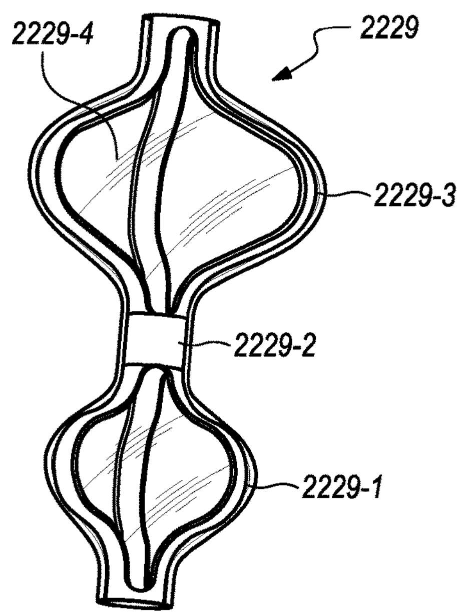


FIG. 33B

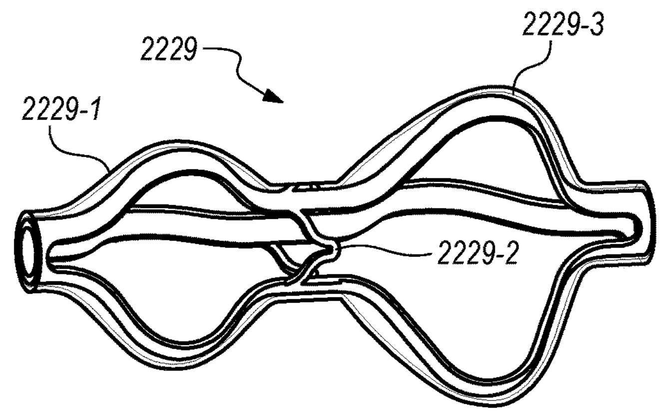


FIG. 33C

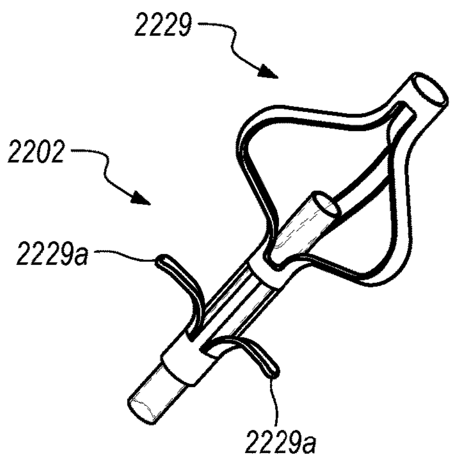


FIG. 34

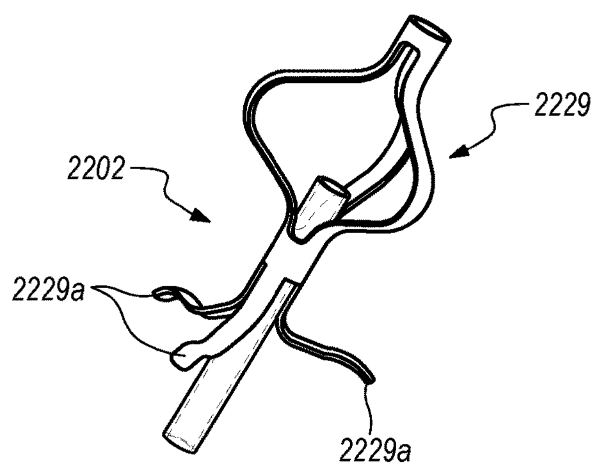


FIG. 35

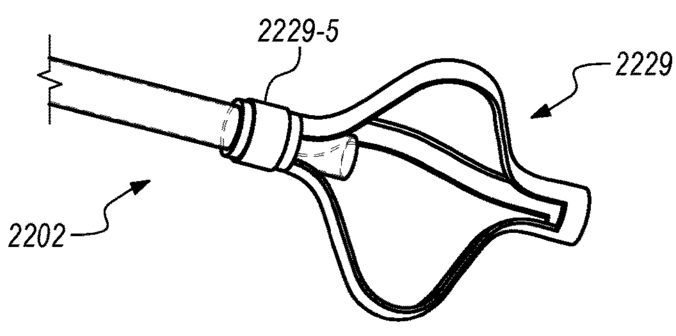


FIG. 36

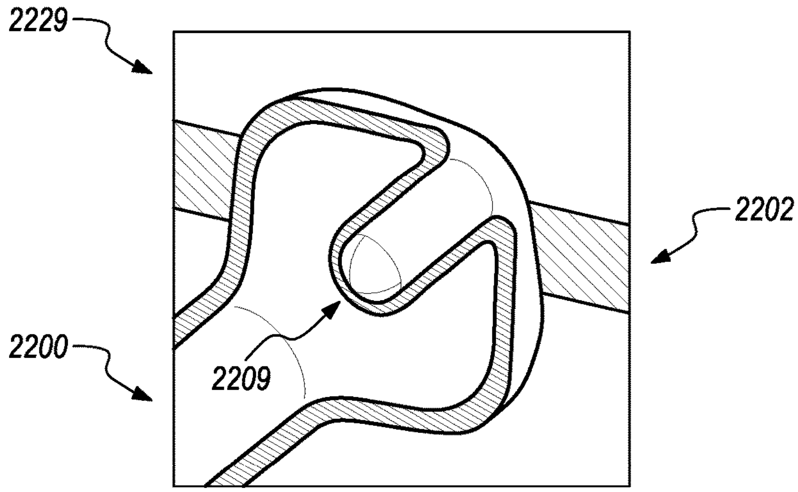


FIG. 37

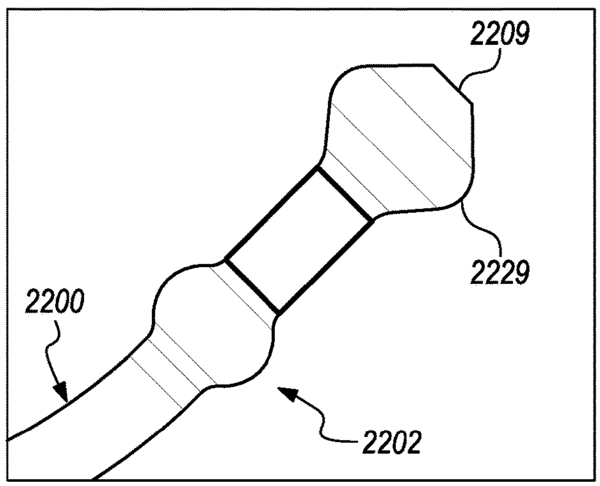


FIG. 38

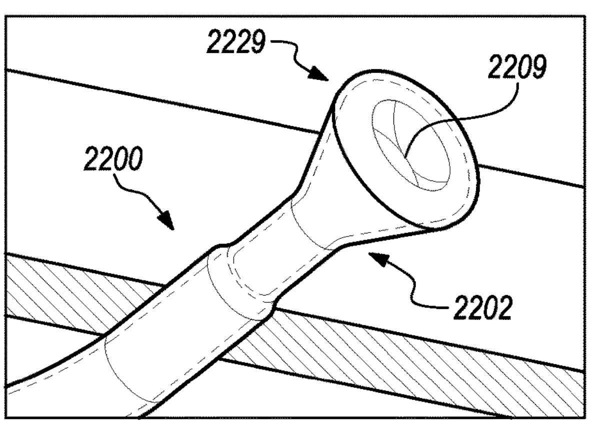


FIG. 39A

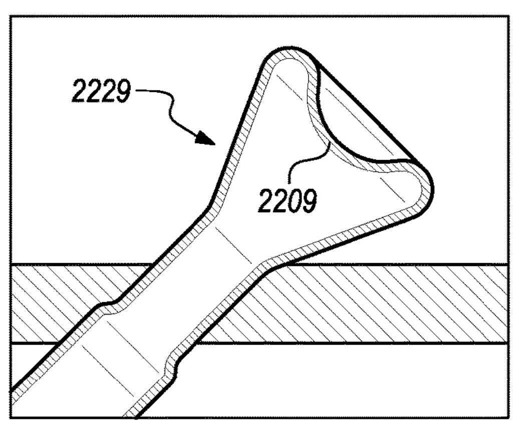


FIG. 39B

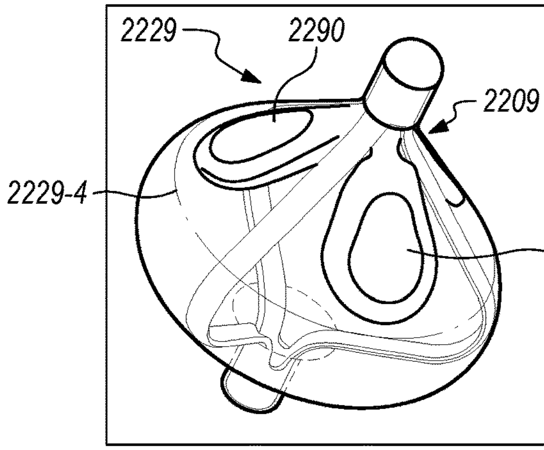


FIG. 40A

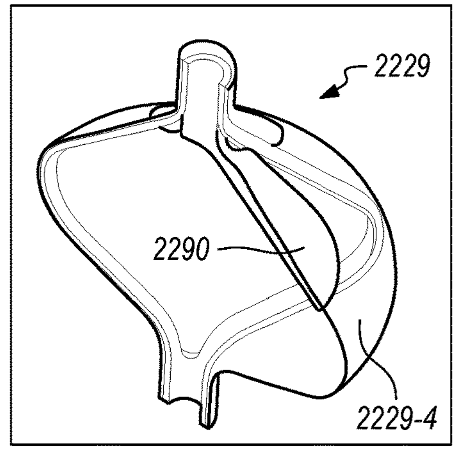


FIG. 40B

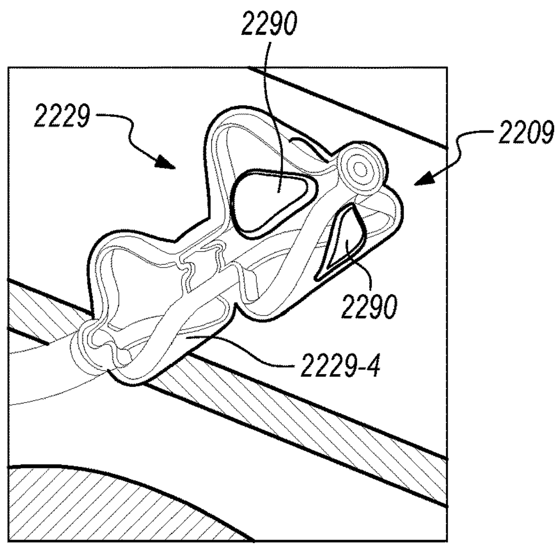


FIG. 40C

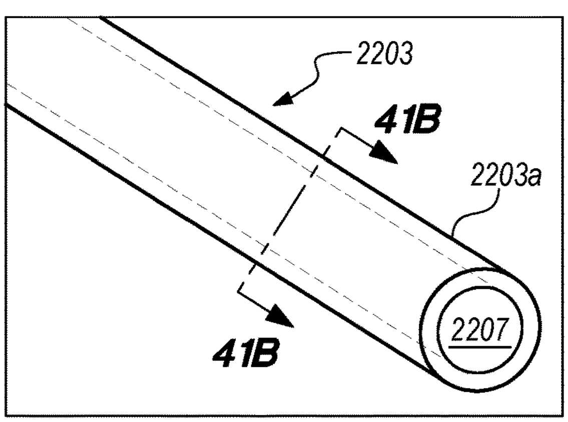


FIG. 41A

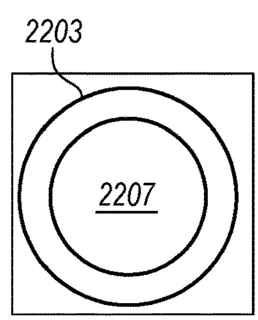


FIG. 41B

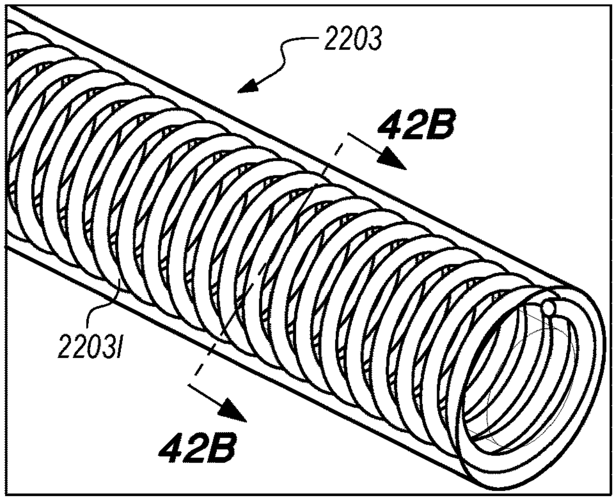


FIG. 42A

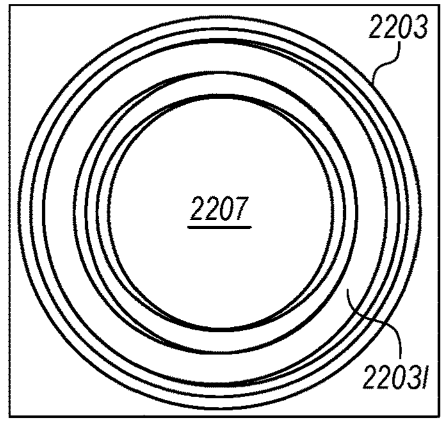


FIG. 42B

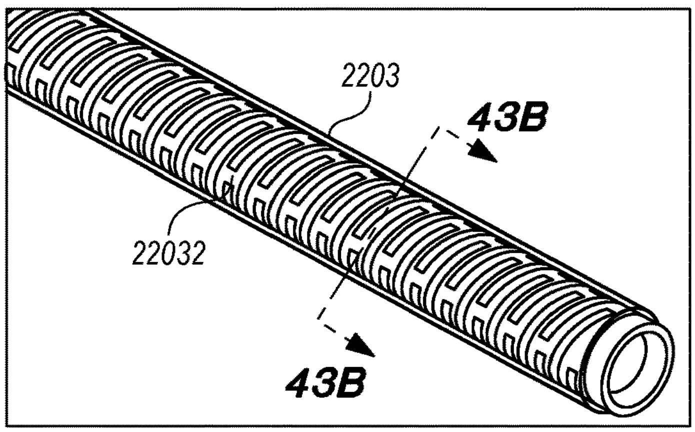


FIG. 43A

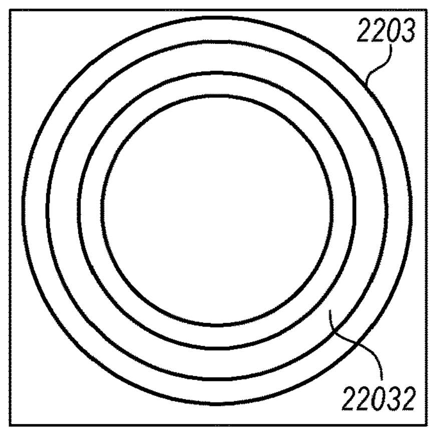


FIG. 43B

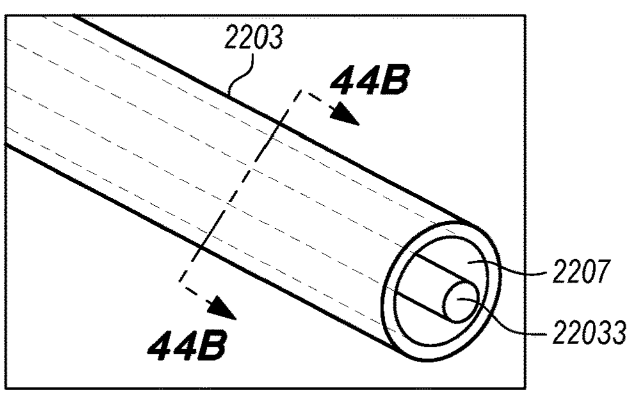


FIG. 44A

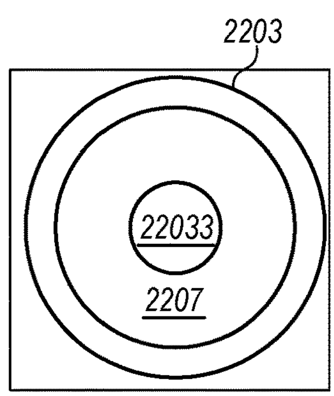


FIG. 44B

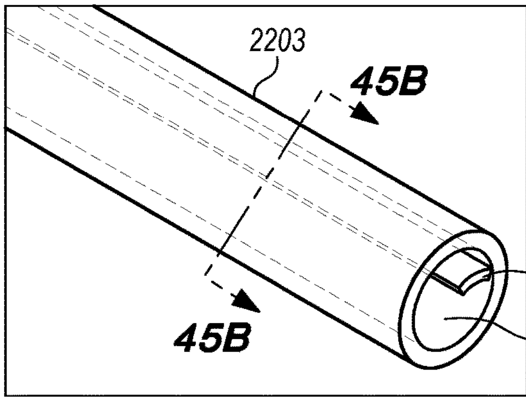


FIG. 45A

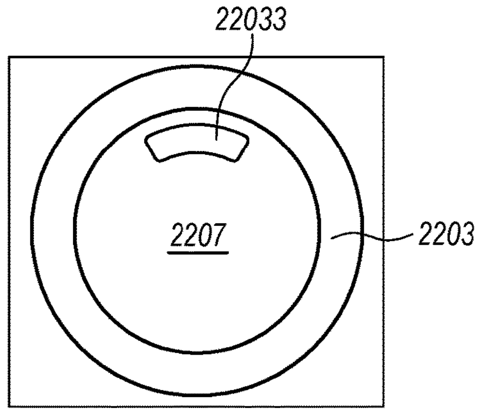


FIG. 45B

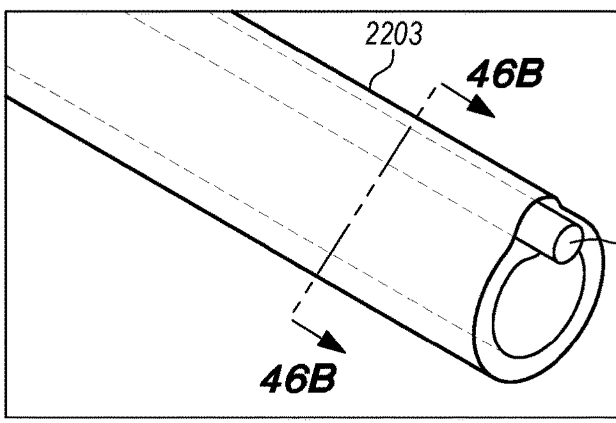


FIG. 46A

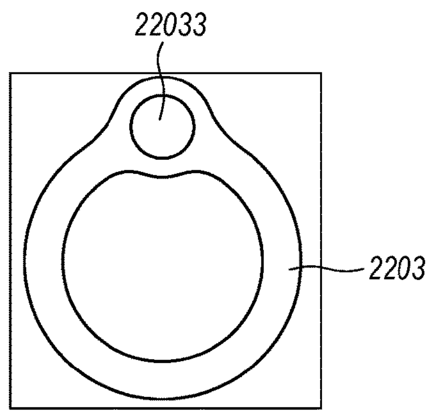


FIG. 46B

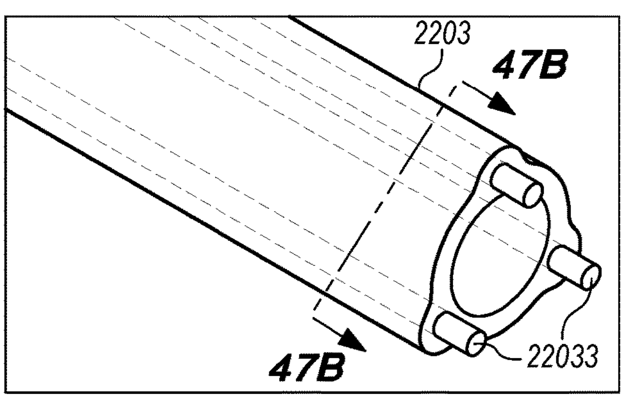


FIG. 47A

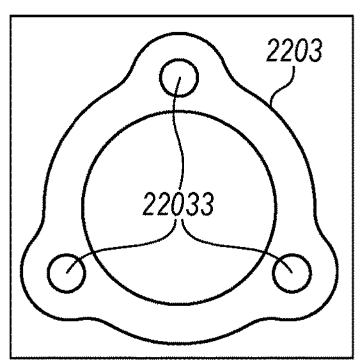


FIG. 47B

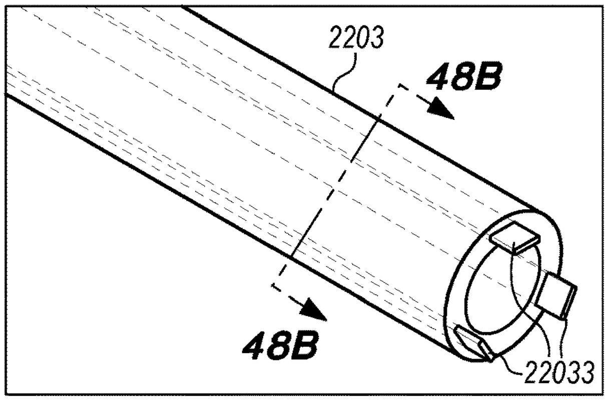


FIG. 48A

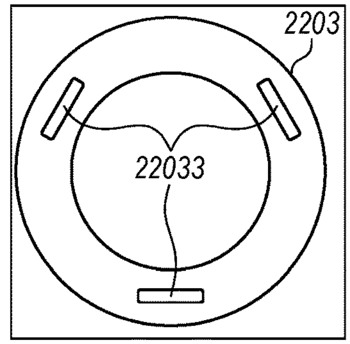


FIG. 48B

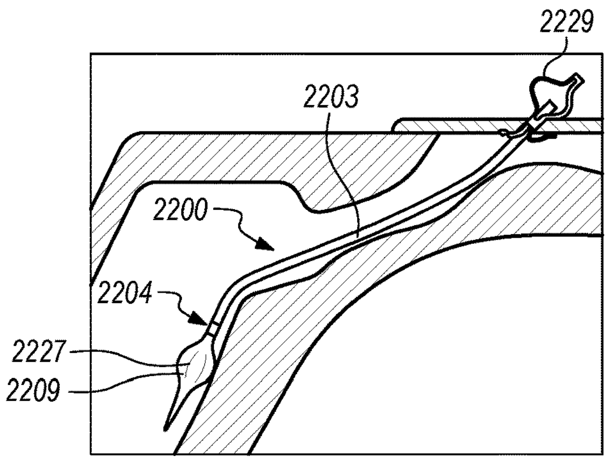


FIG. 49A

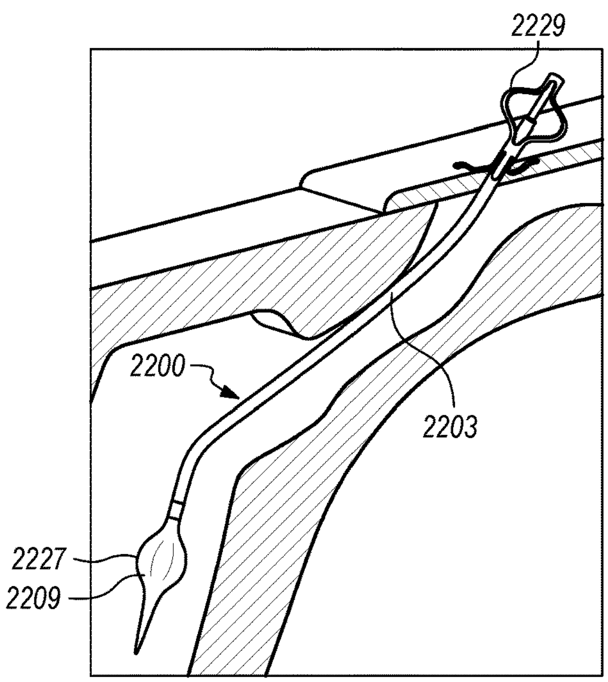


FIG. 49B

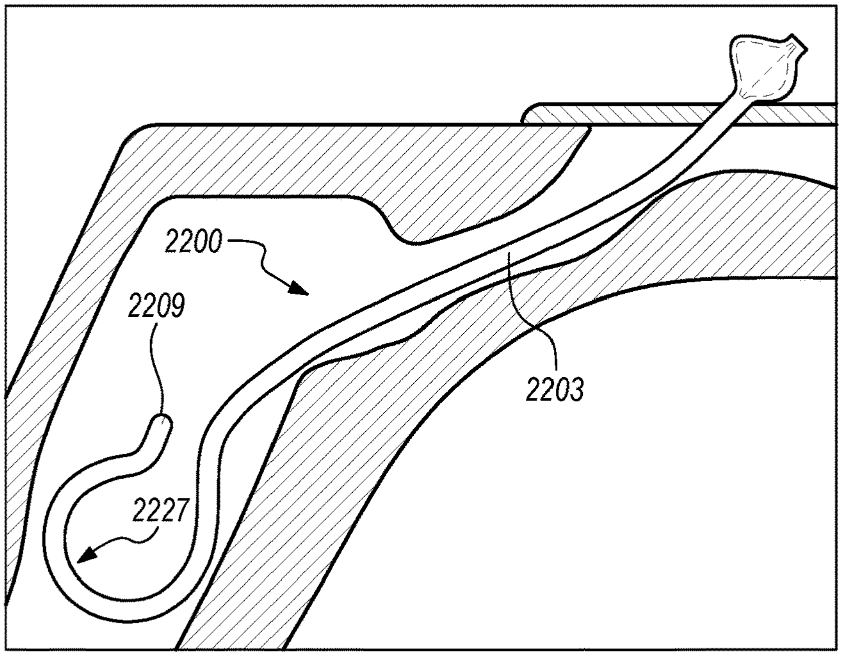


FIG. 50A

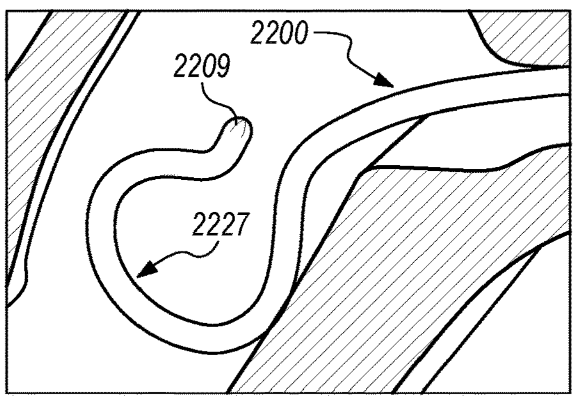


FIG. 50B

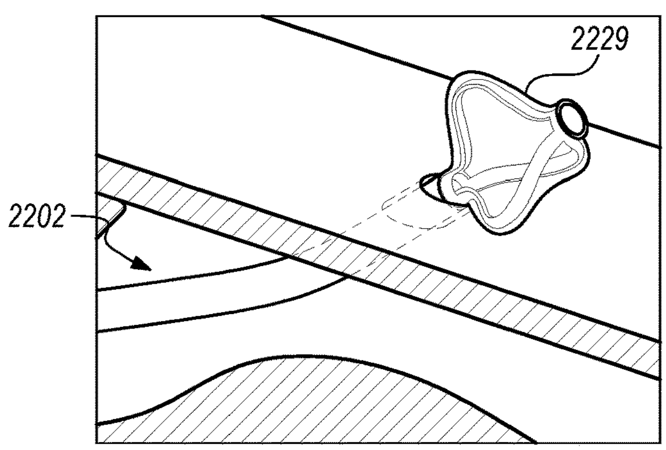


FIG. 50C

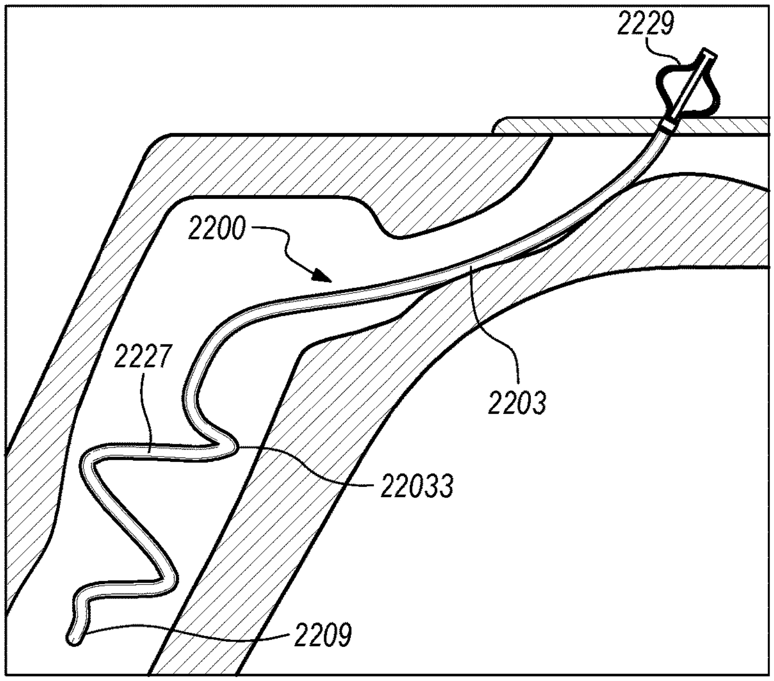


FIG. 51A

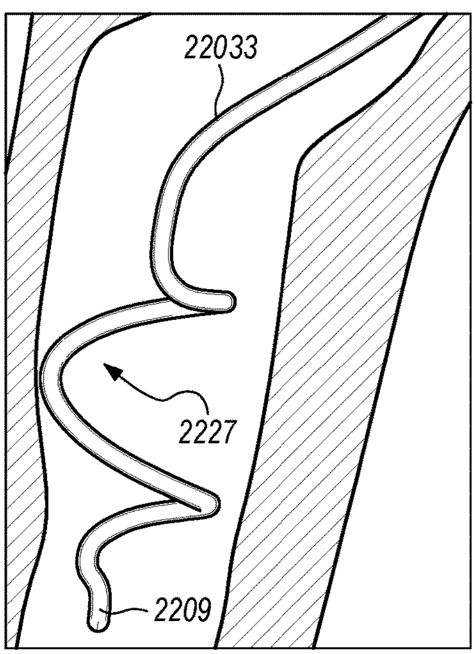


FIG. 51B

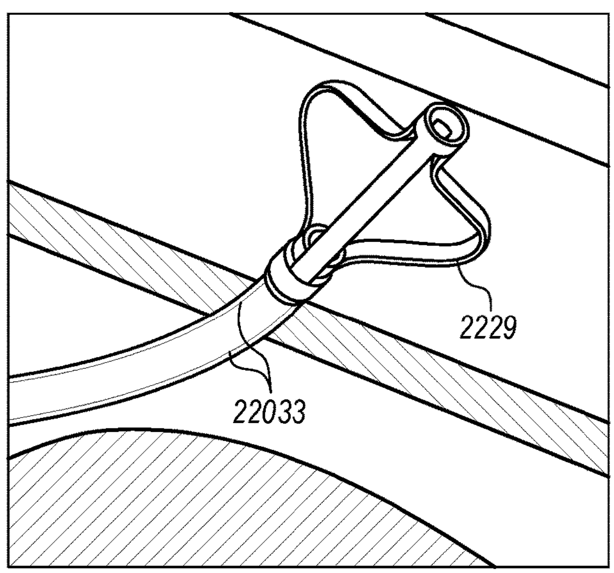


FIG. 51C

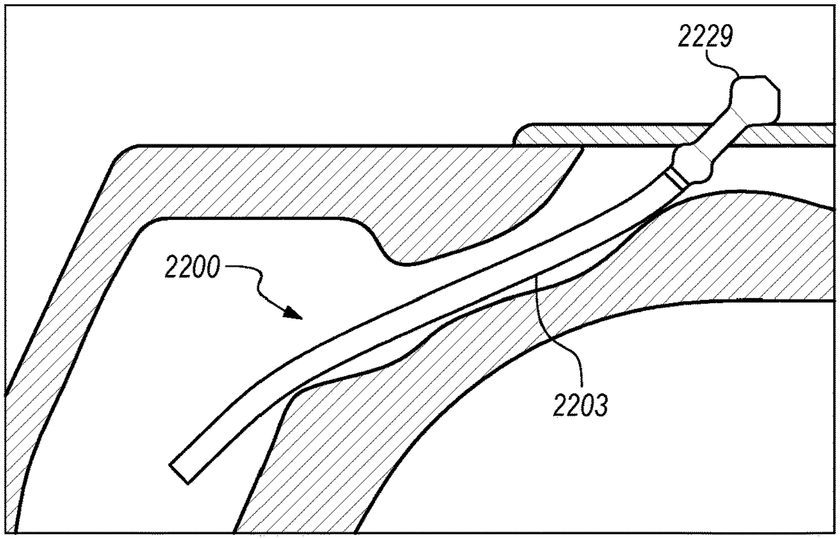


FIG. 52A

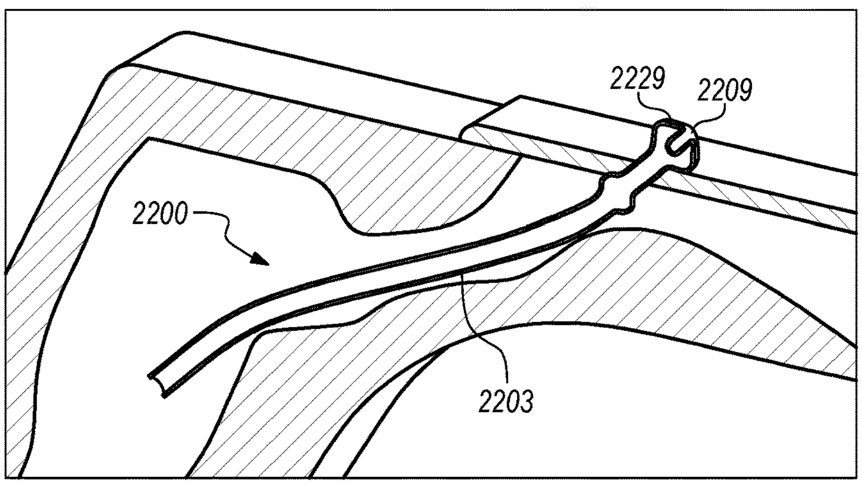


FIG. 52B

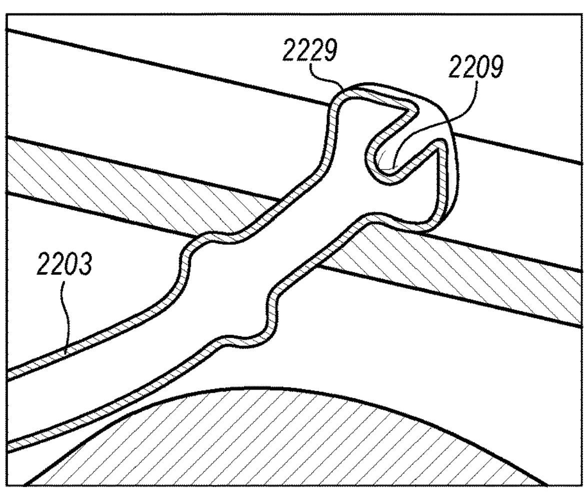


FIG. 52C

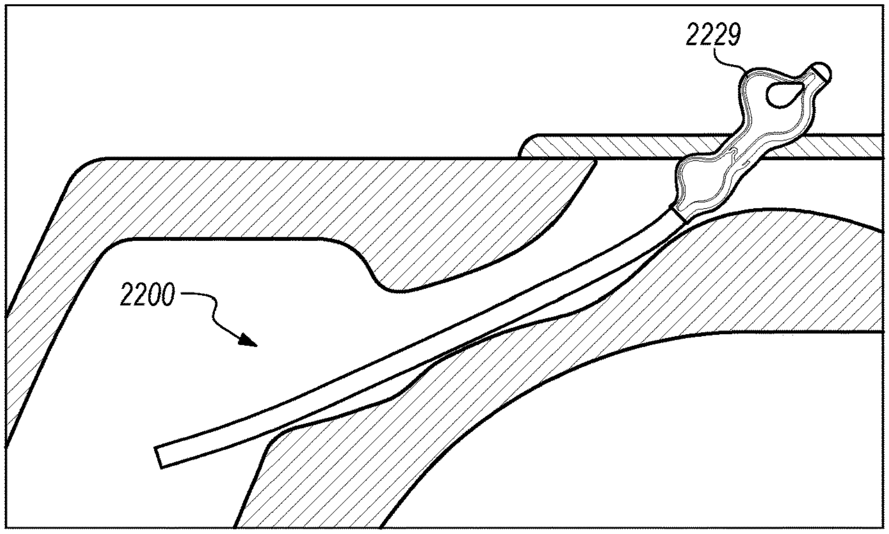


FIG. 53

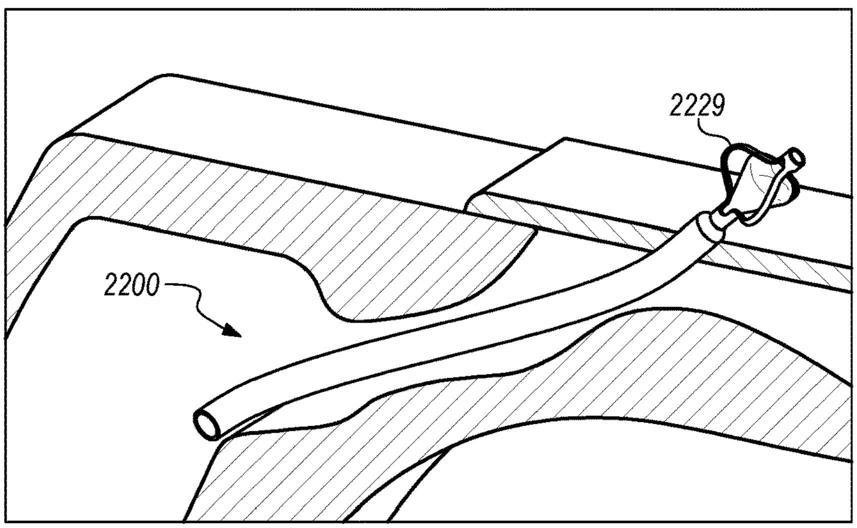


FIG. 54A

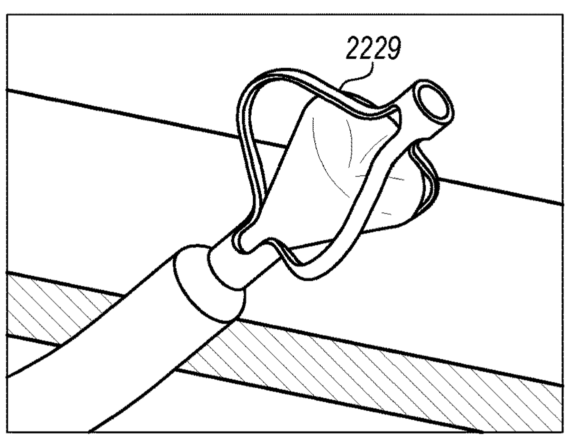


FIG. 54B

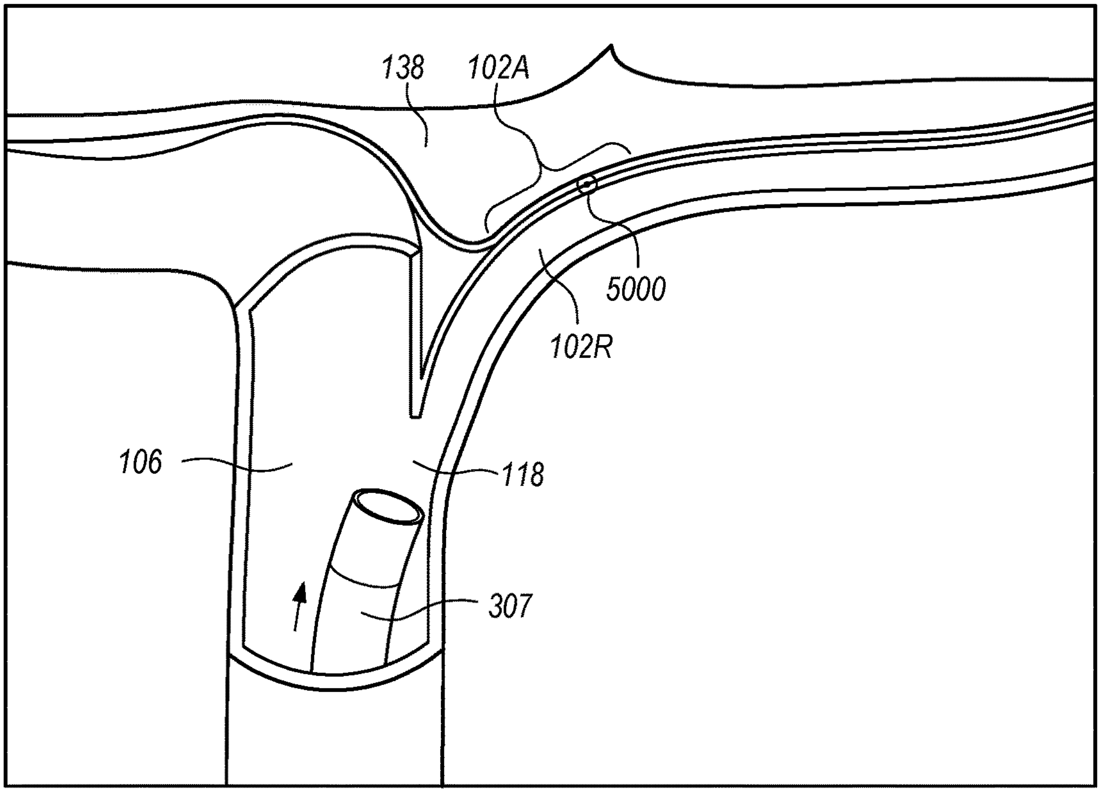


FIG. 55A

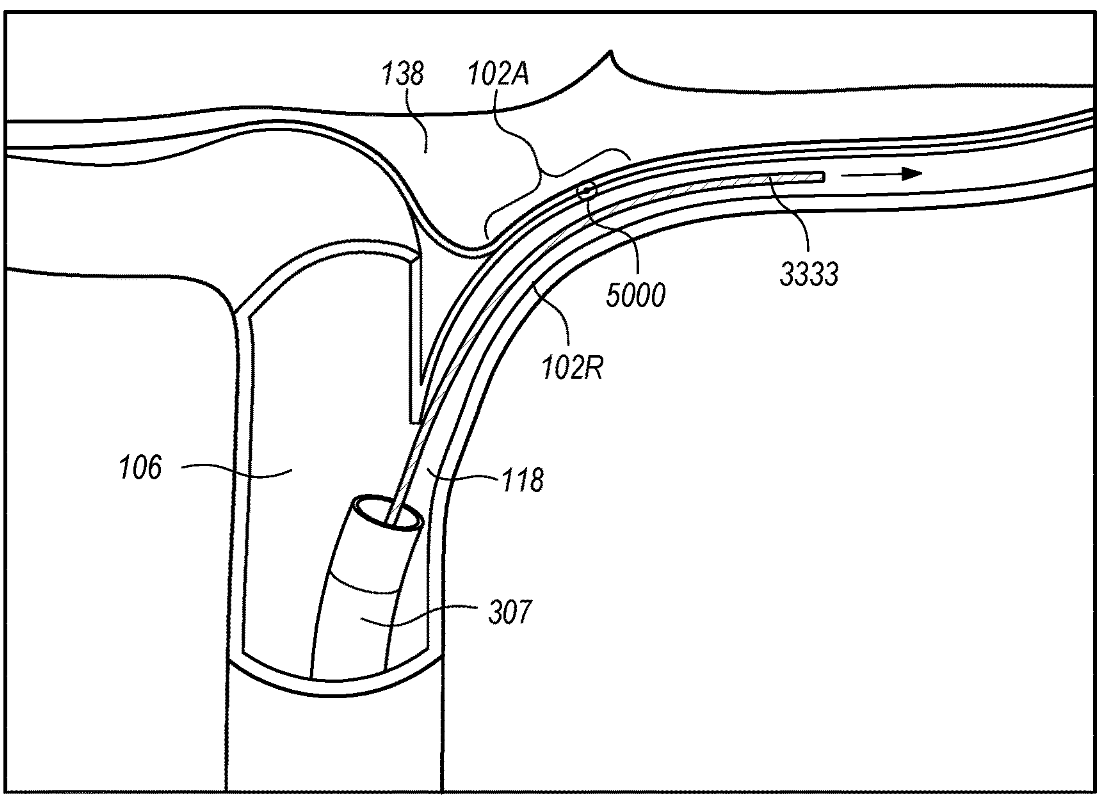


FIG. 55B

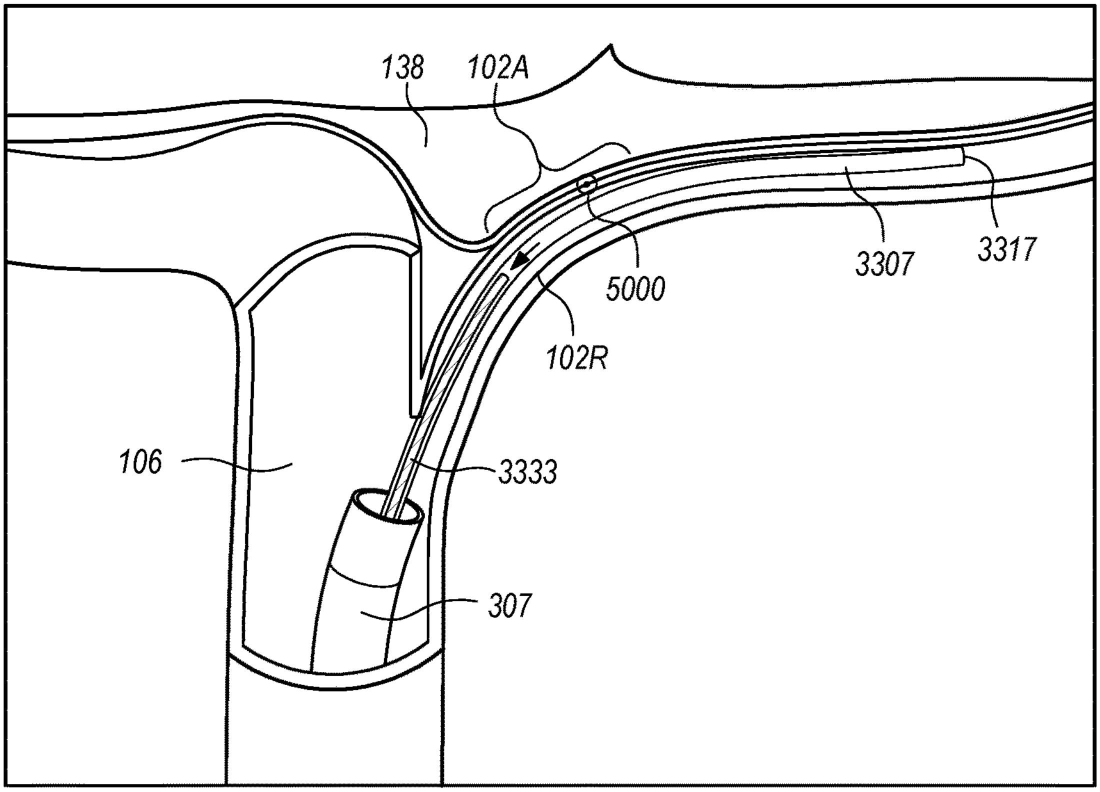


FIG. 55C

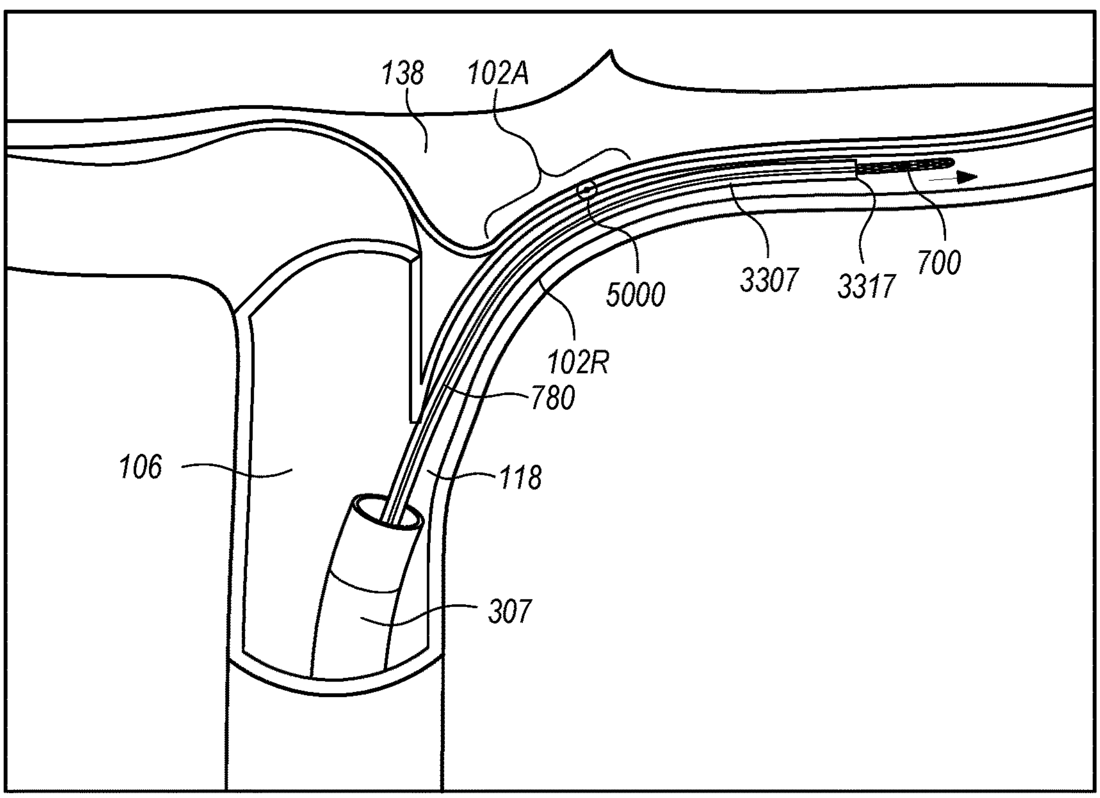


FIG. 55D

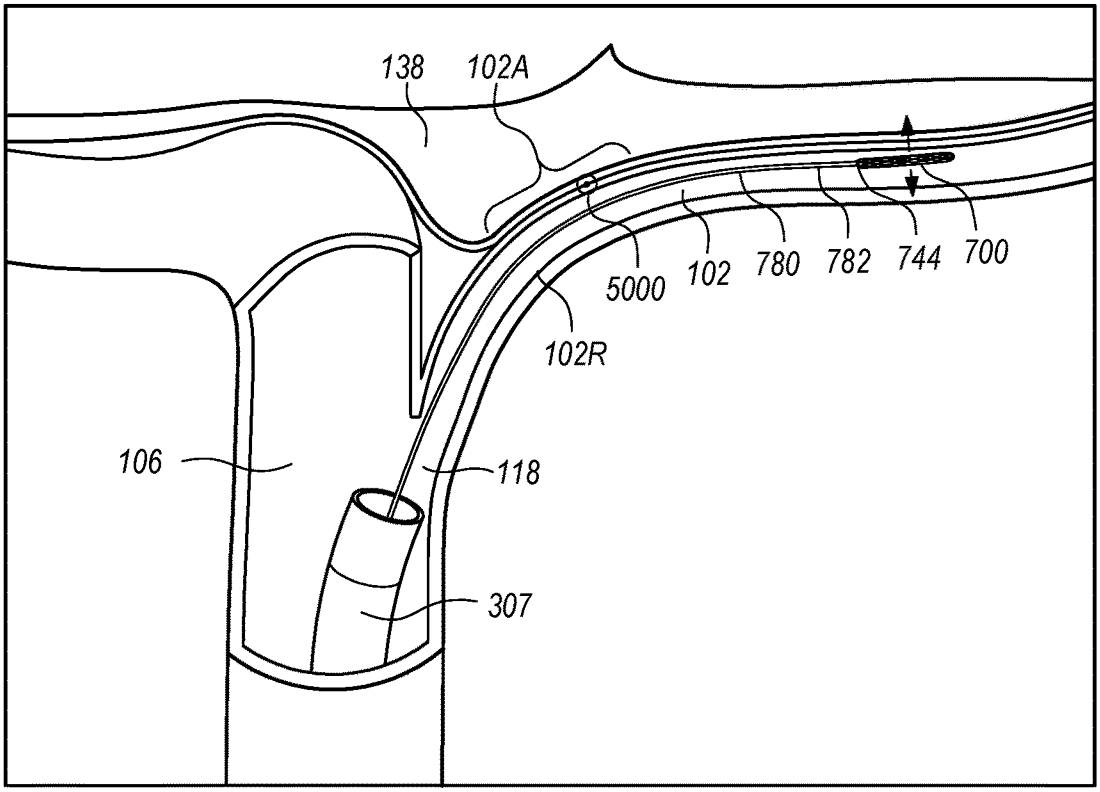


FIG. 55E

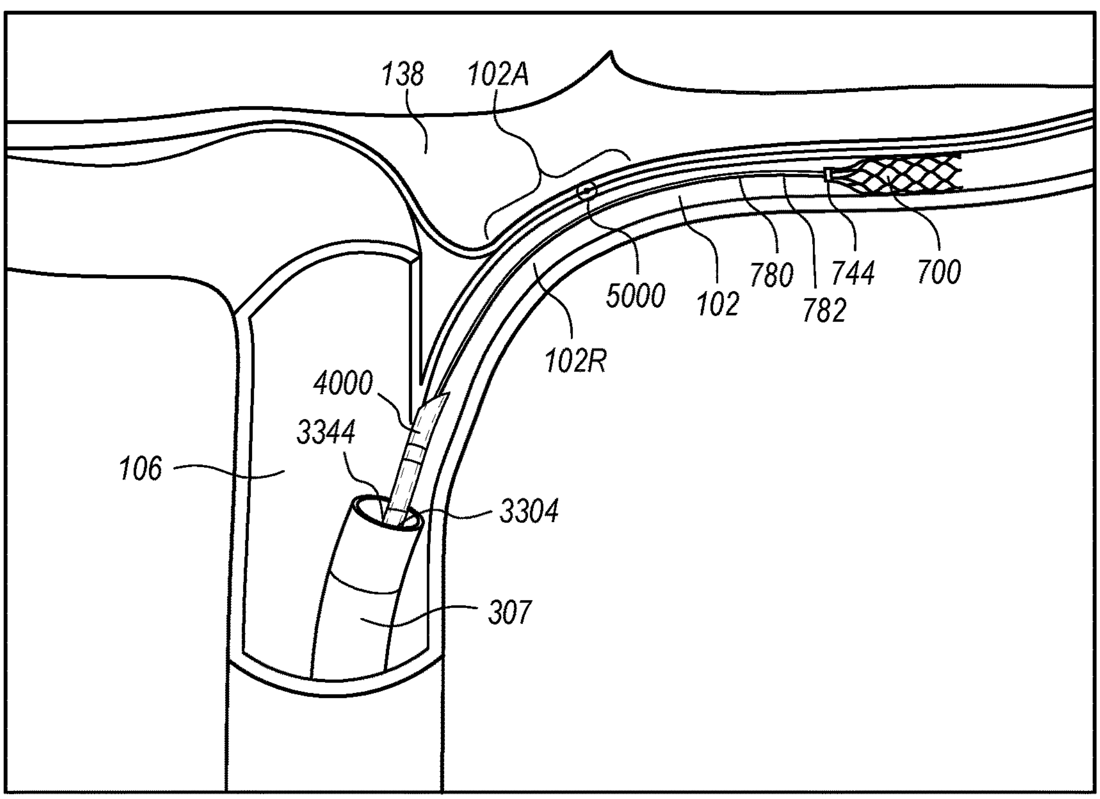


FIG. 55F

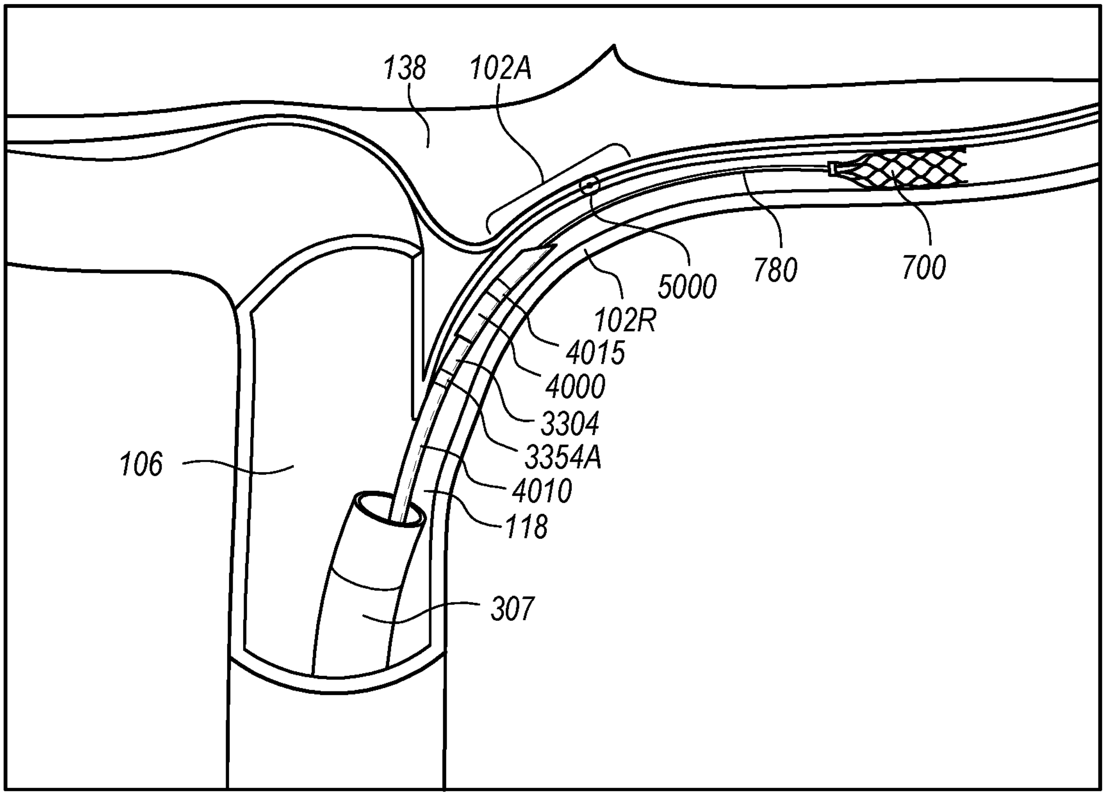


FIG. 55G

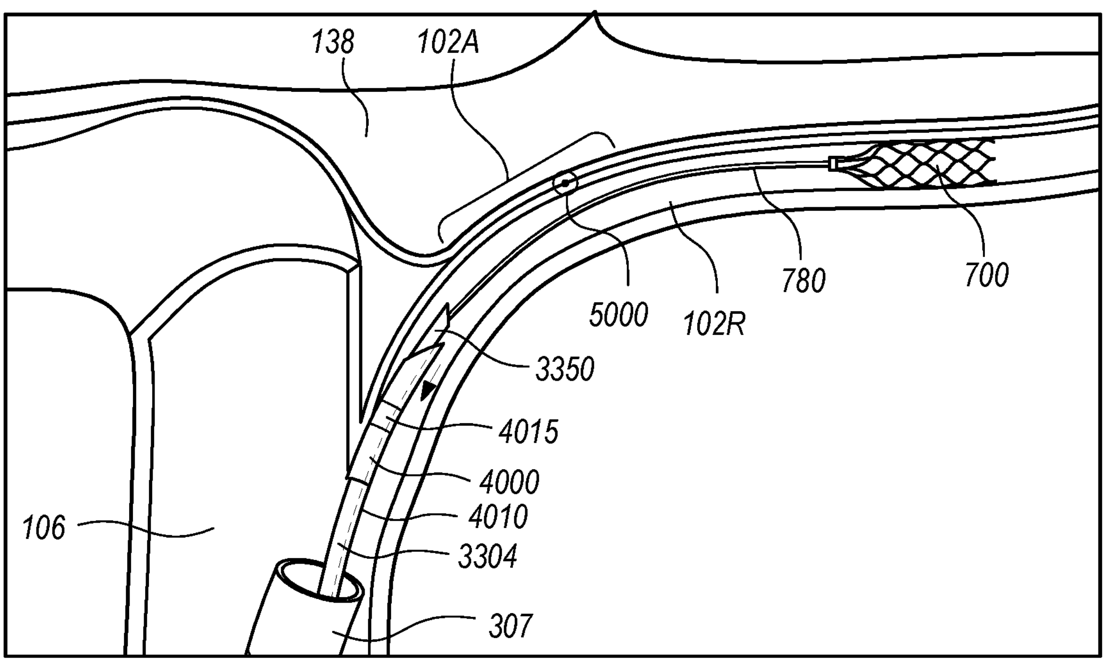


FIG. 55H

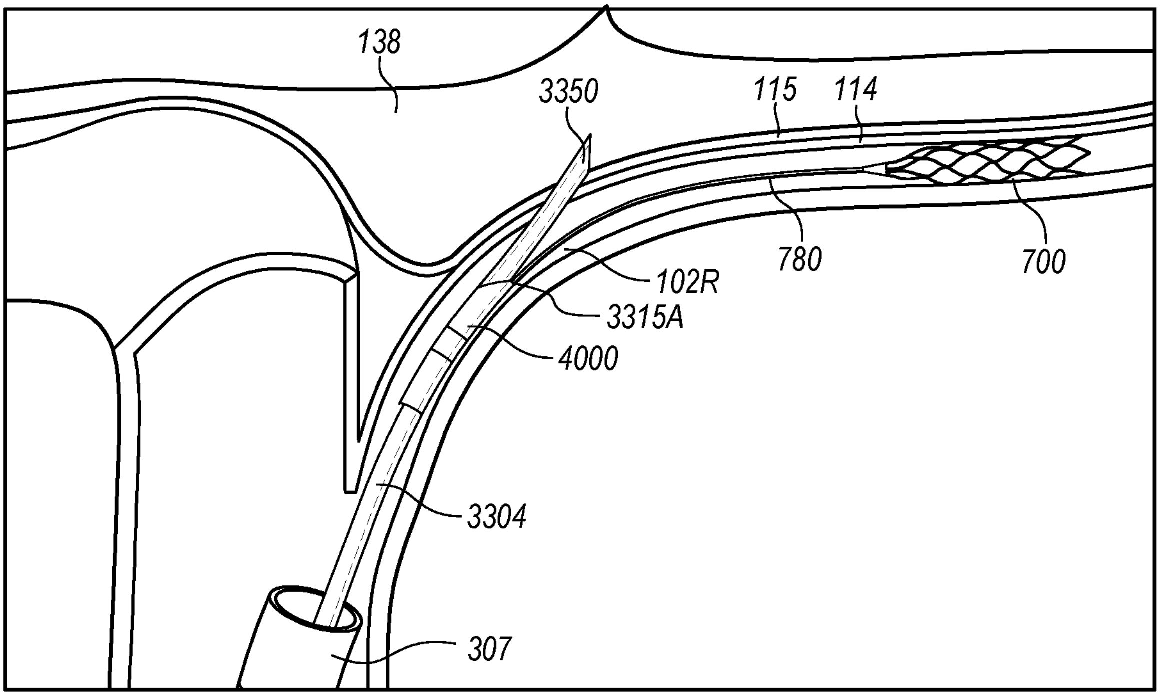


FIG. 55I

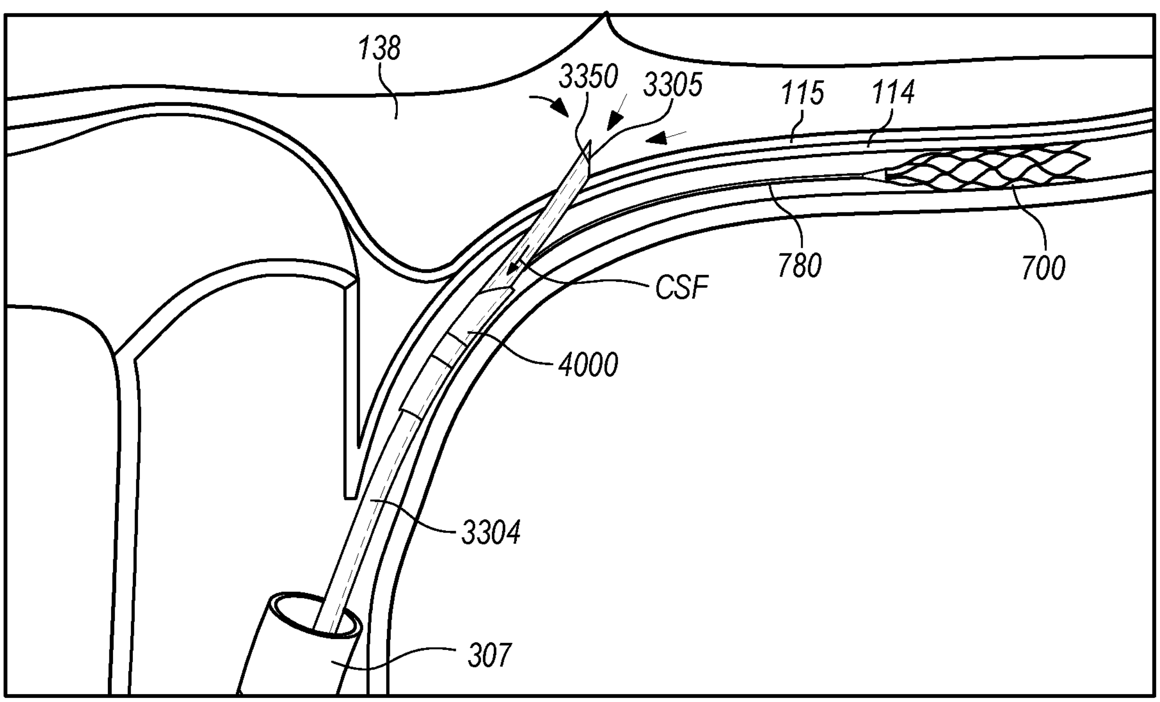


FIG. 55J

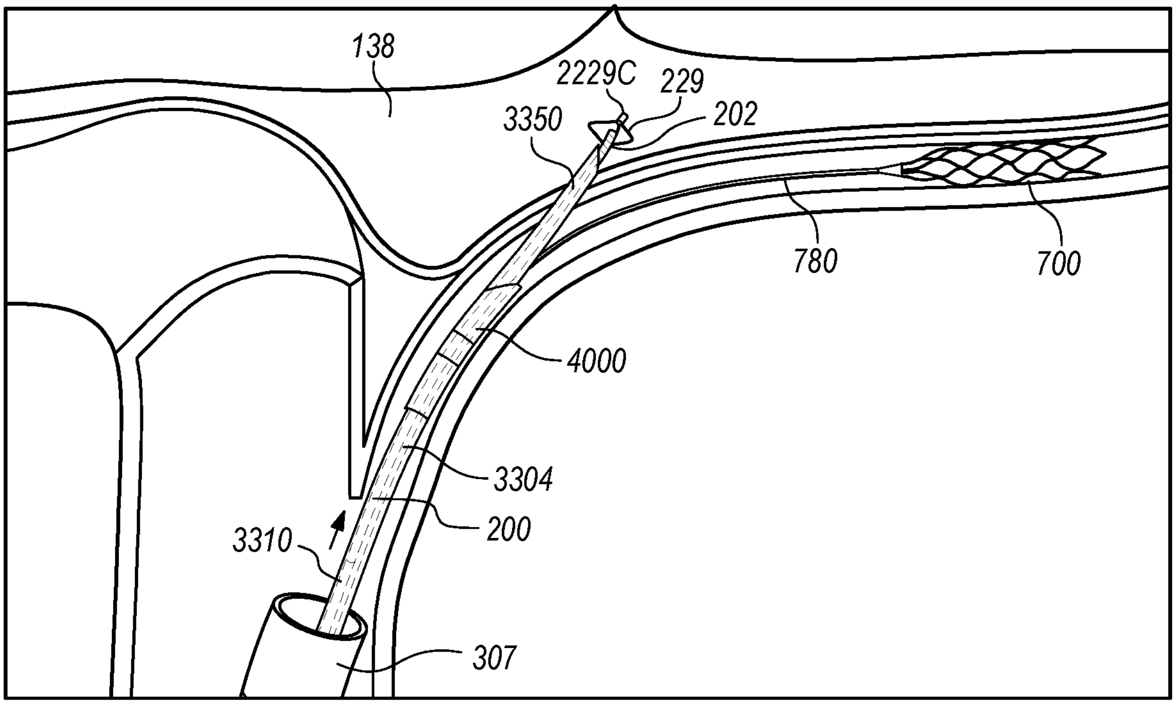


FIG. 55K

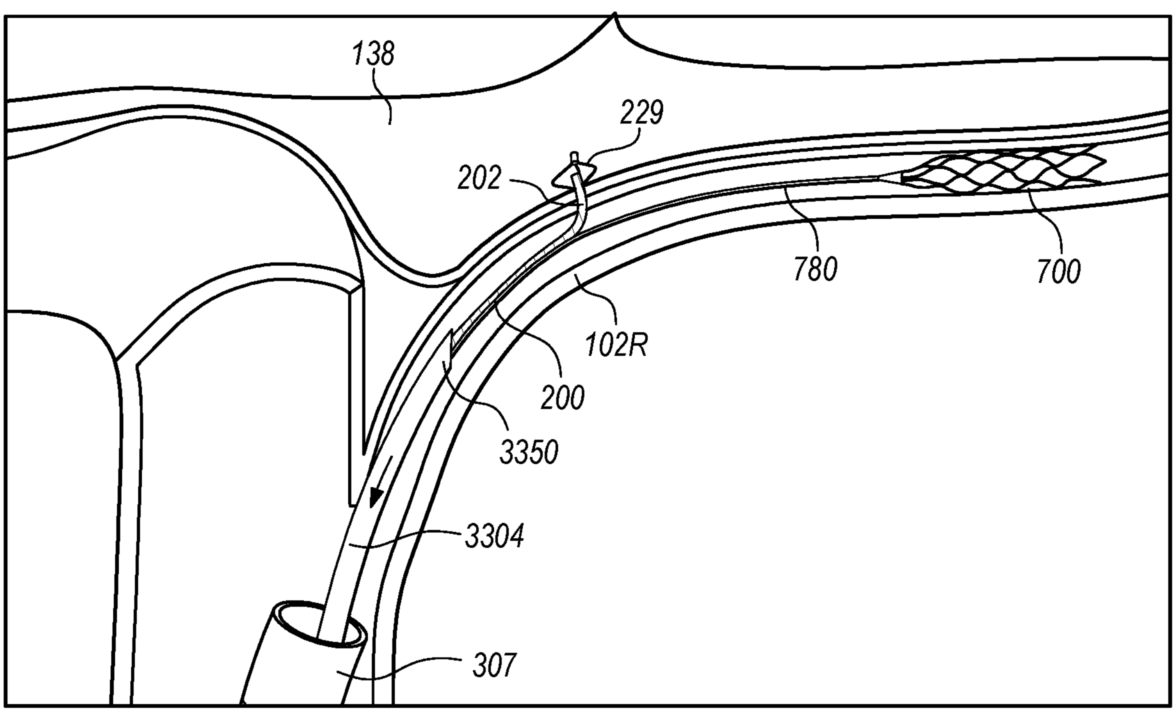


FIG. 55L

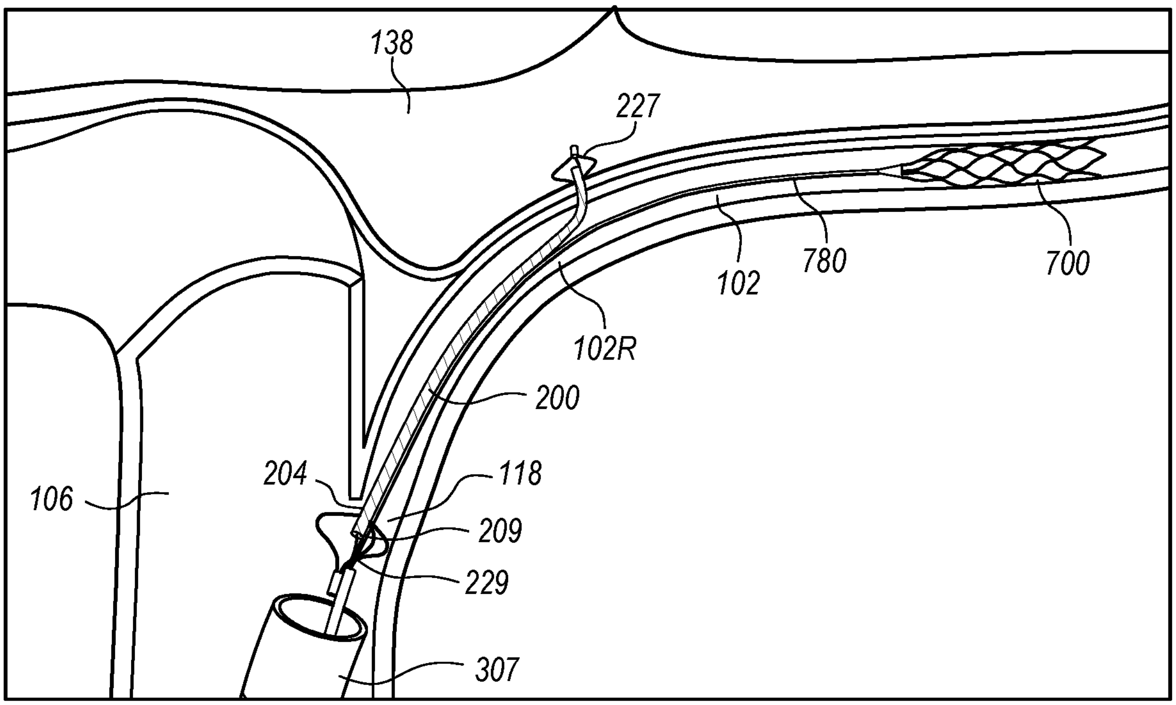


FIG. 55M

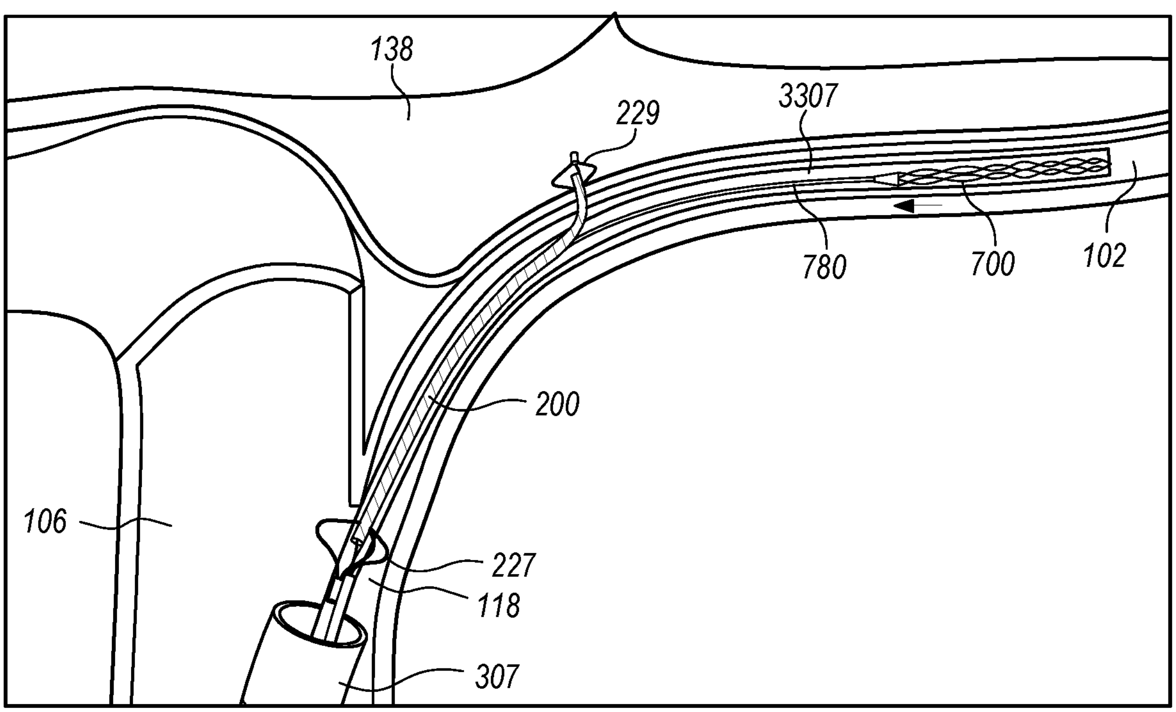


FIG. 55N

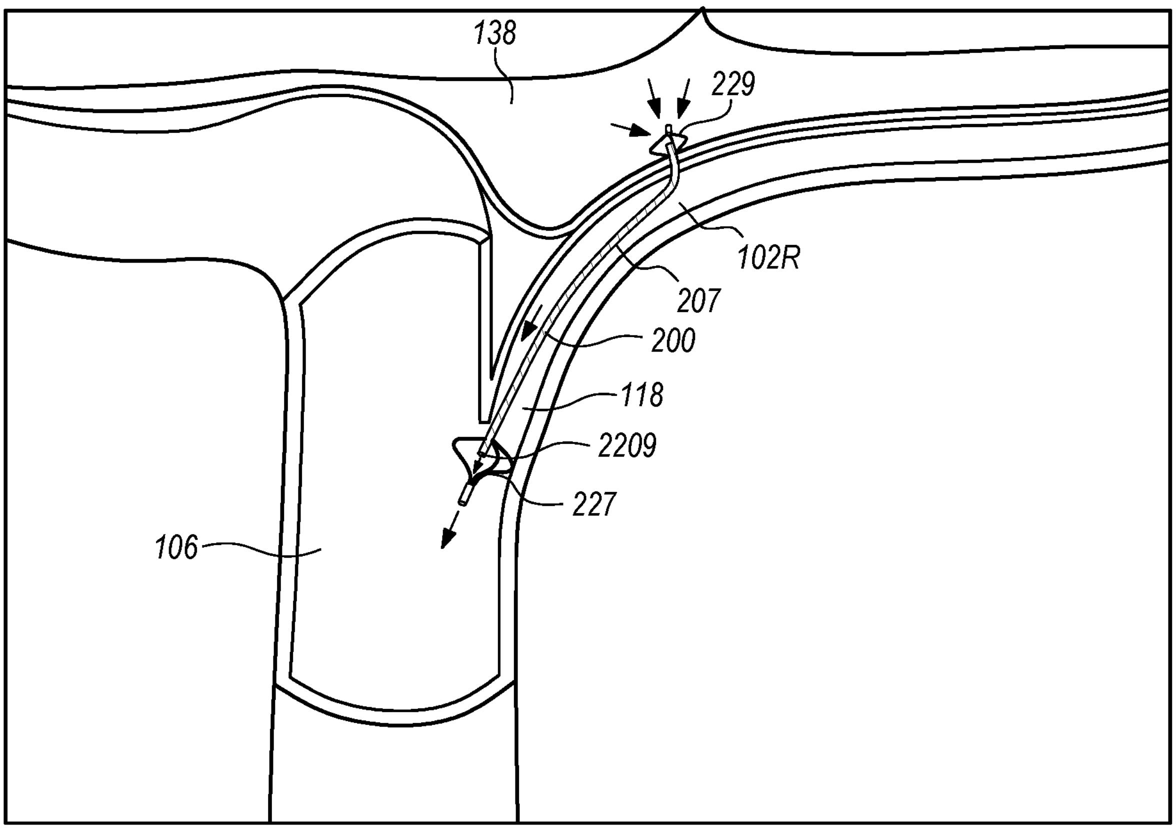


FIG. 55O

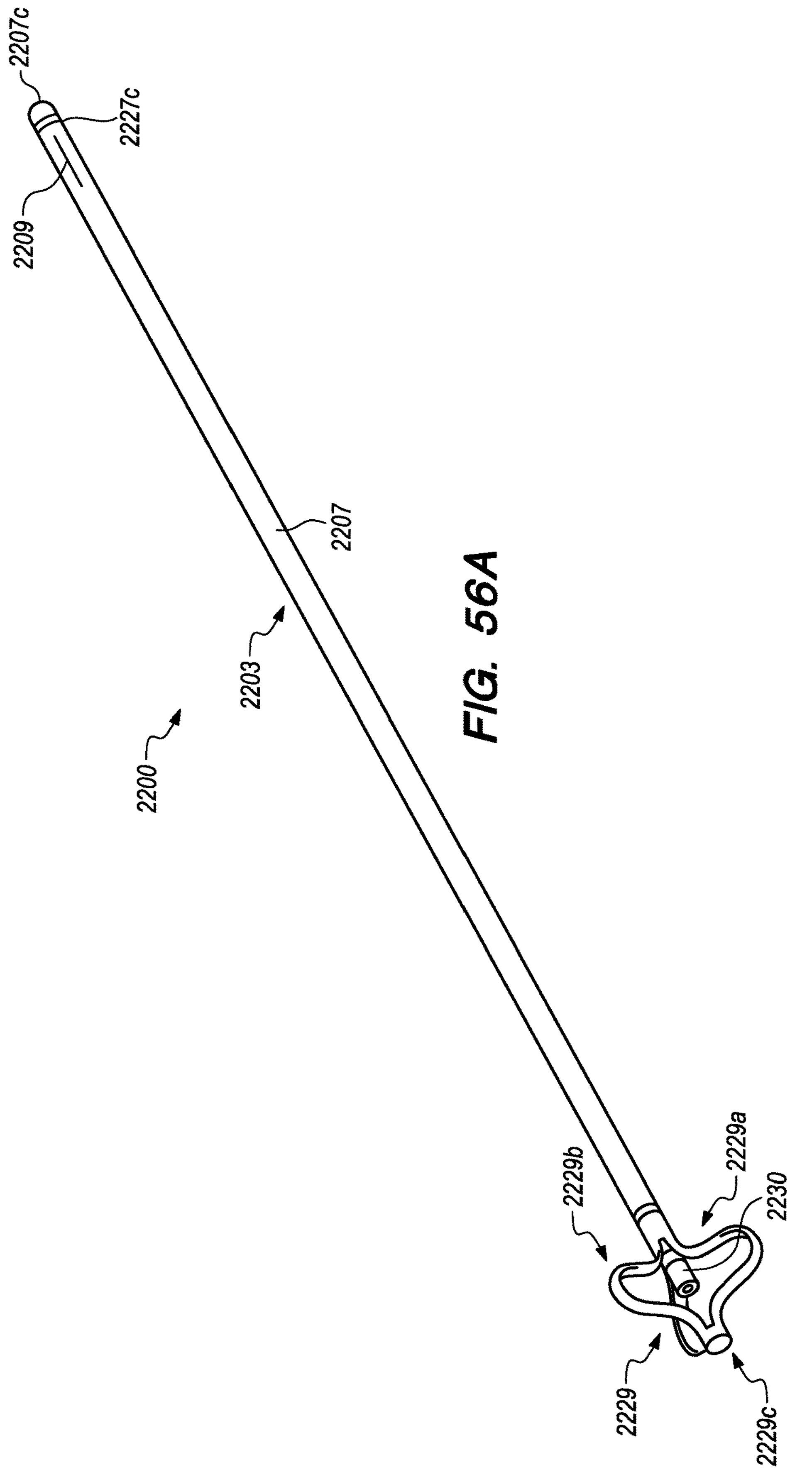


FIG. 56A

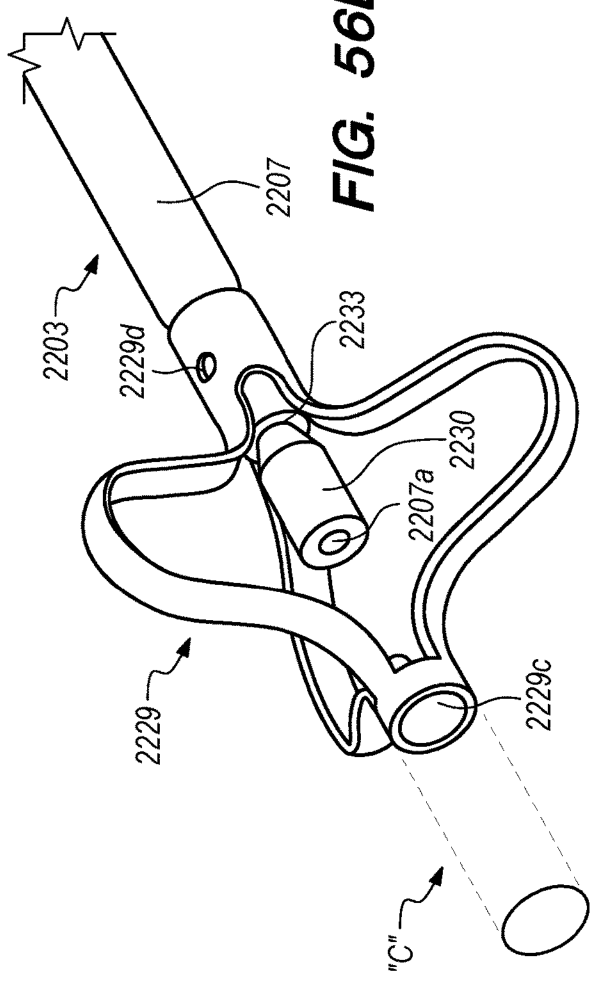


FIG. 56B

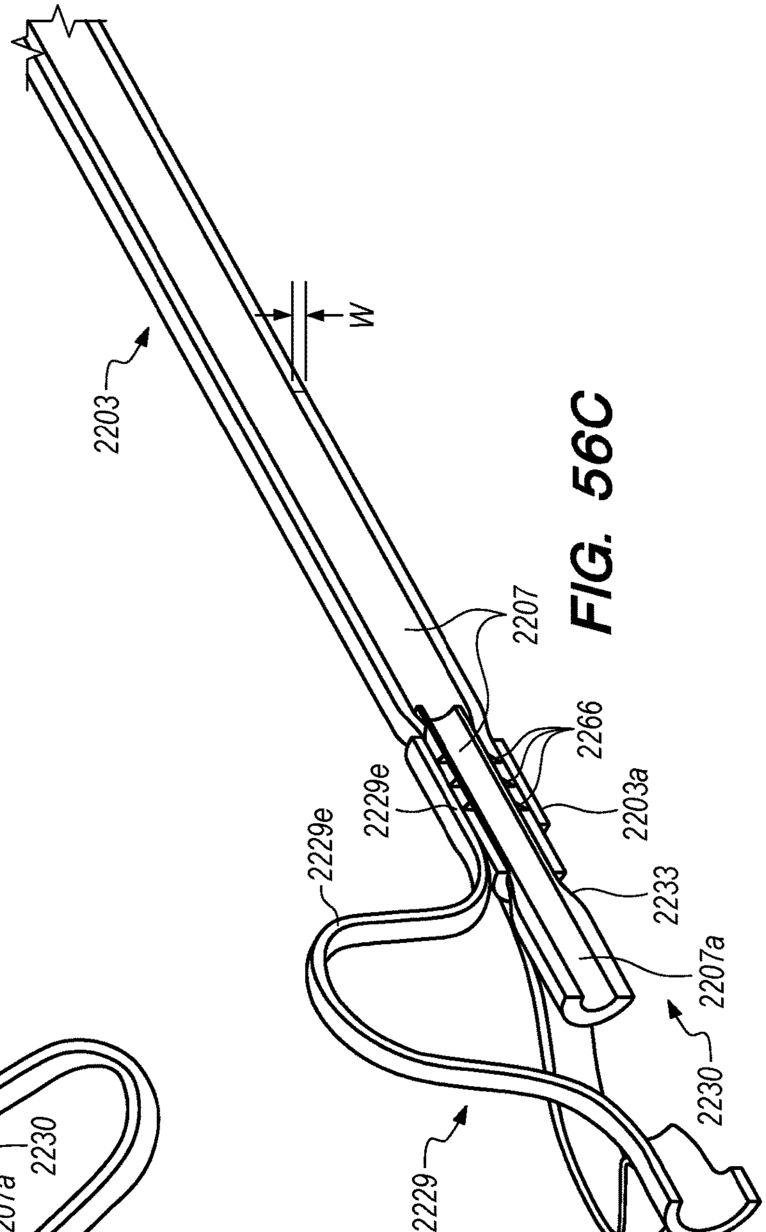


FIG. 56C

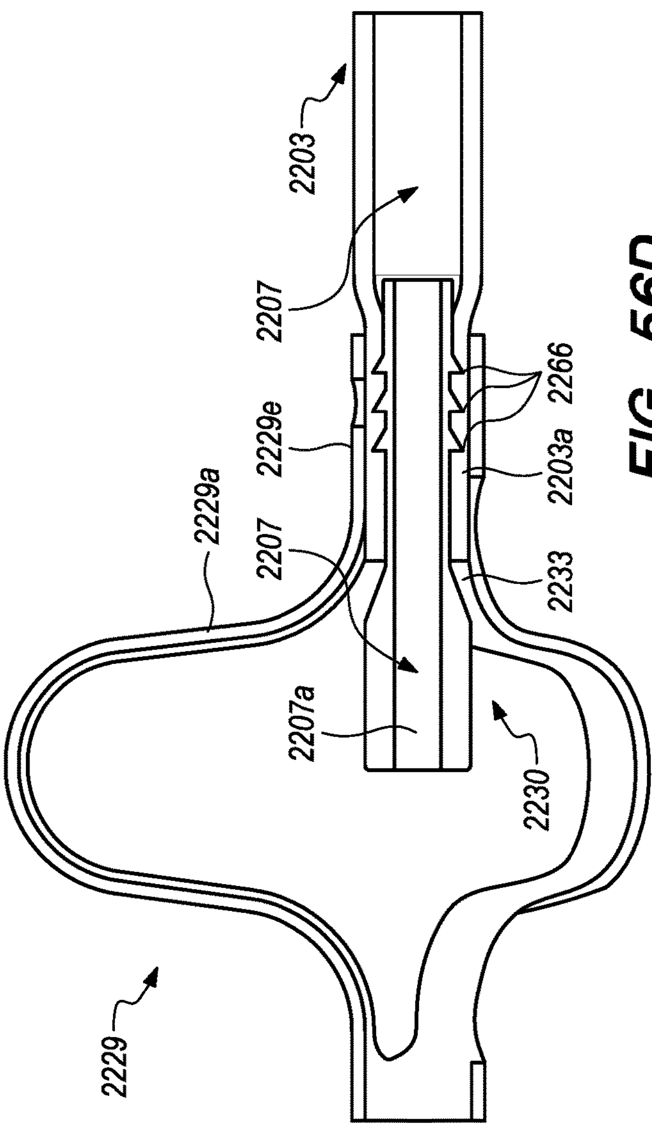


FIG. 56D

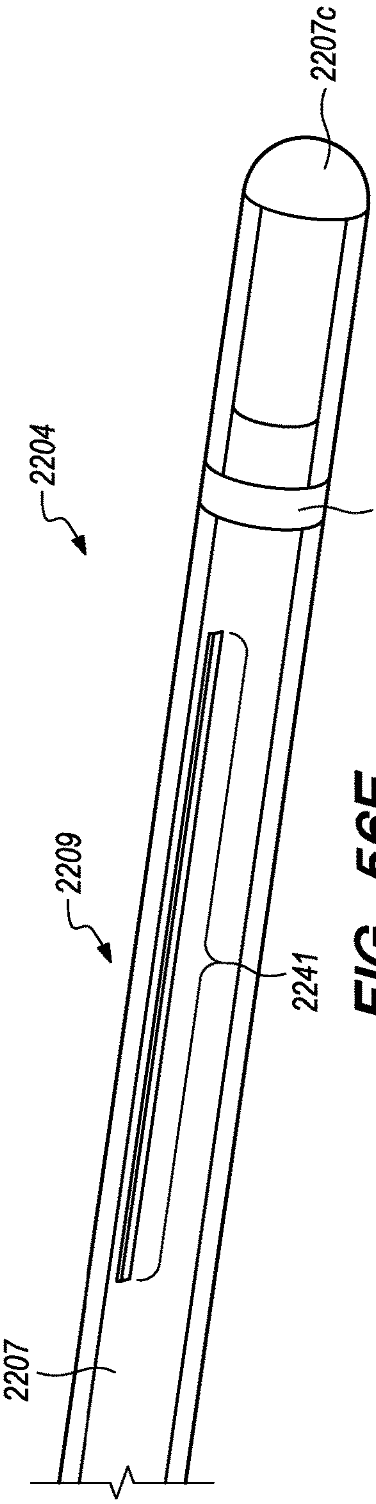


FIG. 56E

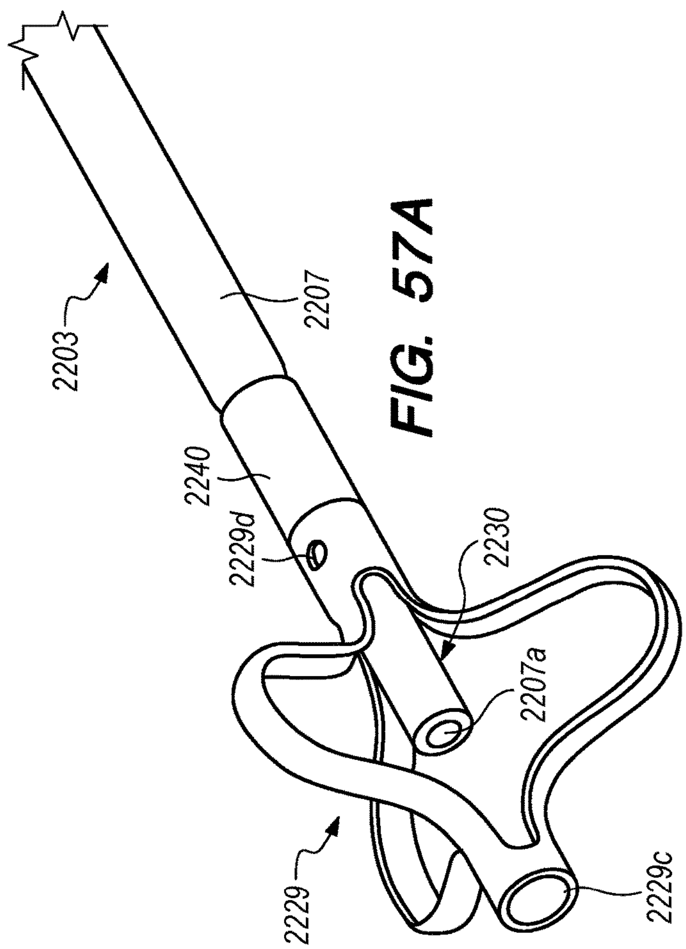


FIG. 57A

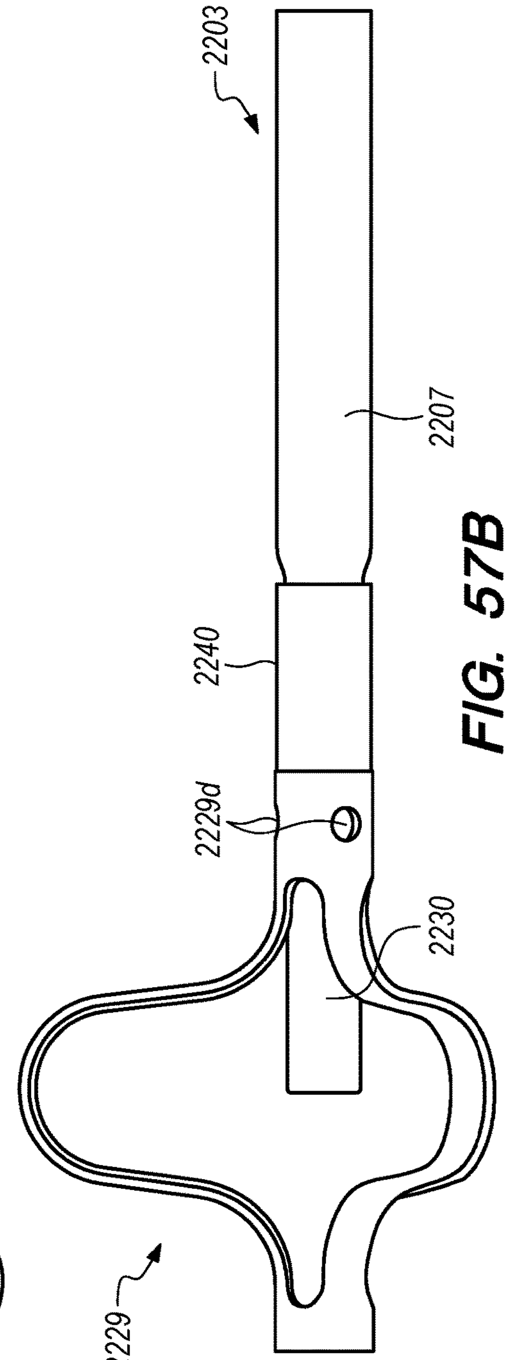


FIG. 57B

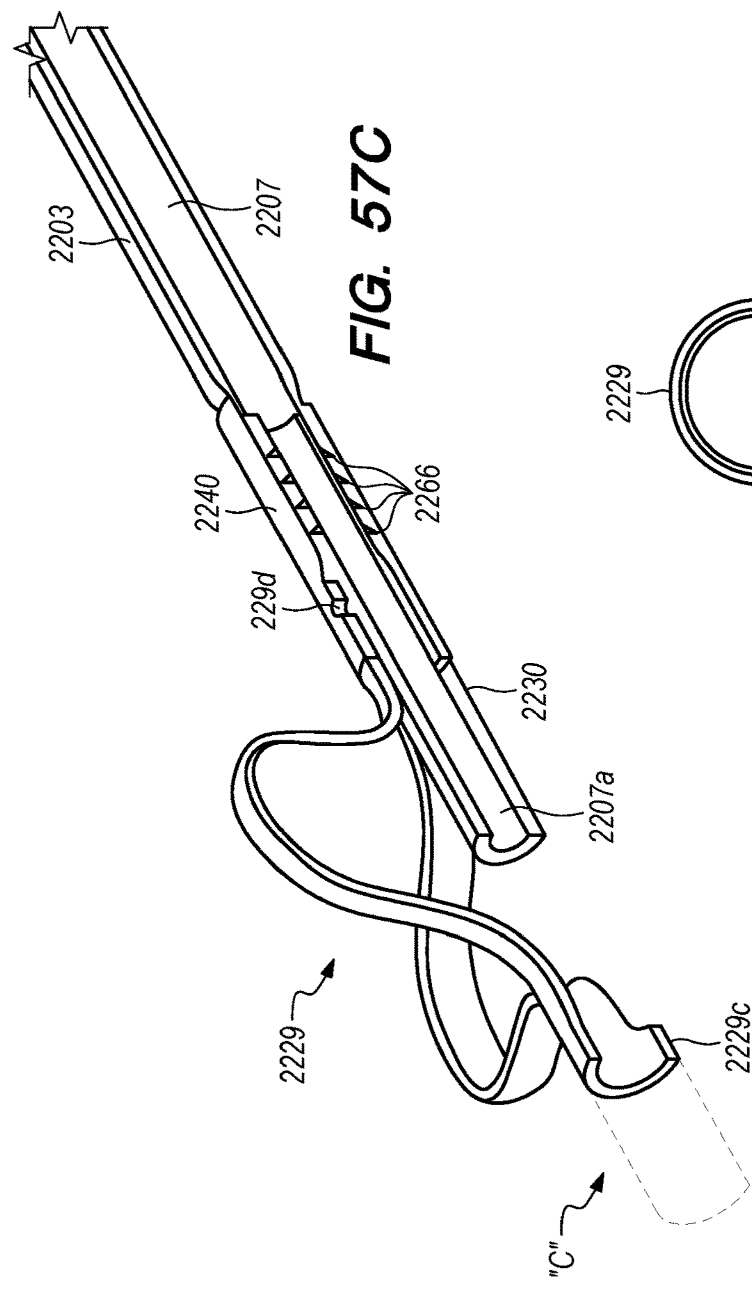


FIG. 57C

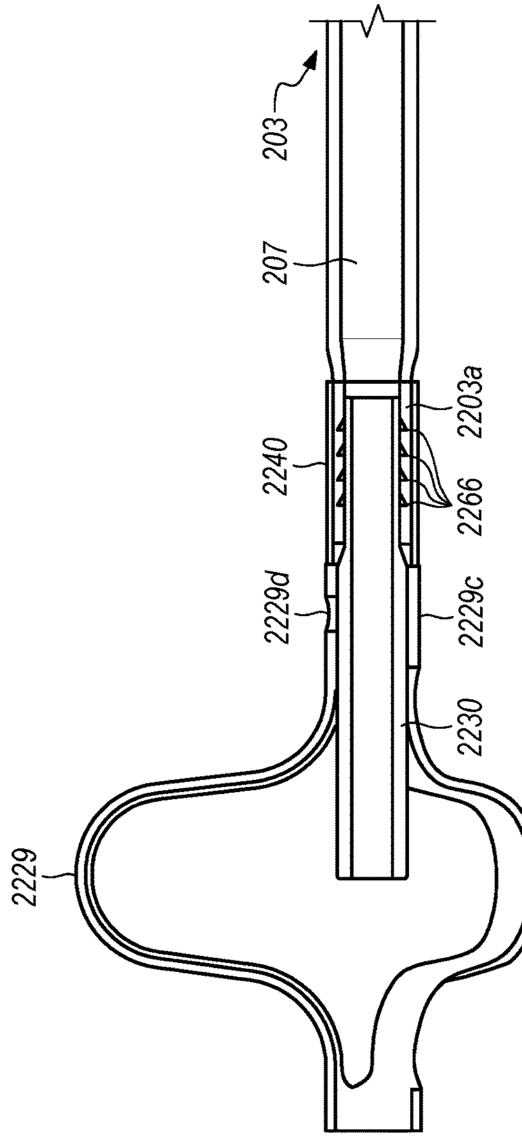


FIG. 57D

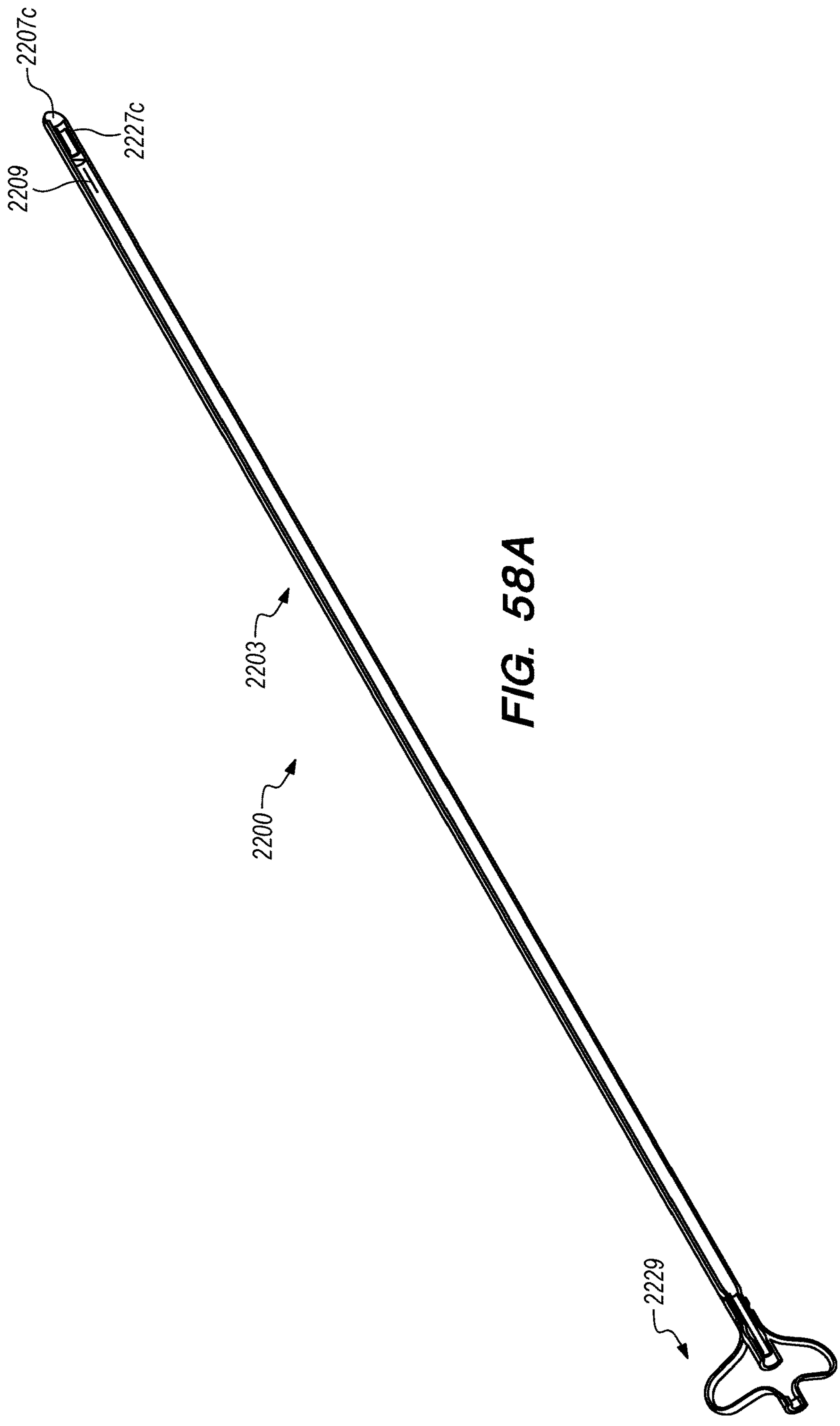


FIG. 58A

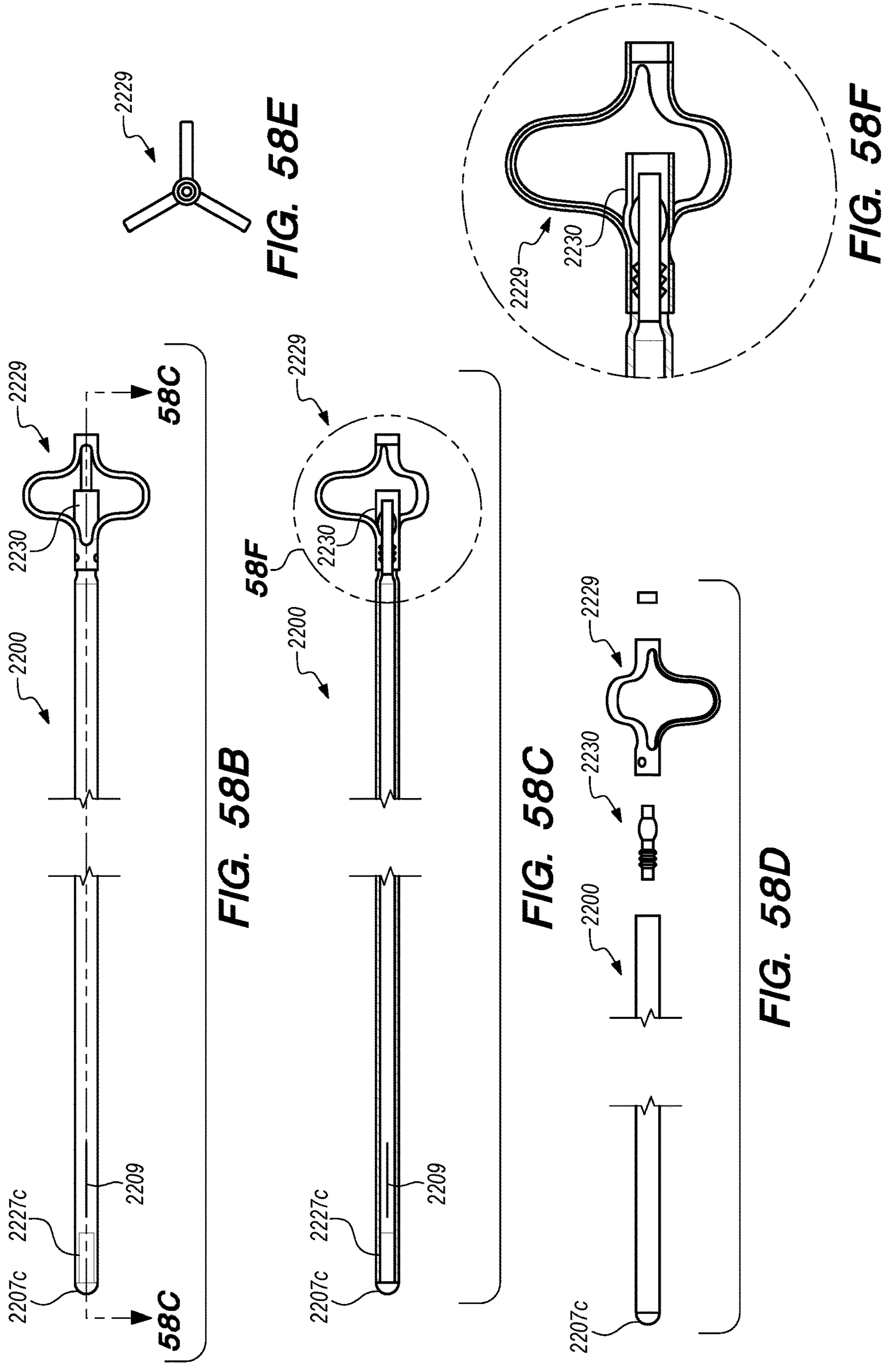


FIG. 58B
FIG. 58C
FIG. 58D
FIG. 58E
FIG. 58F
2229
2230
2200
2209
2227c
2207c
58C
58F

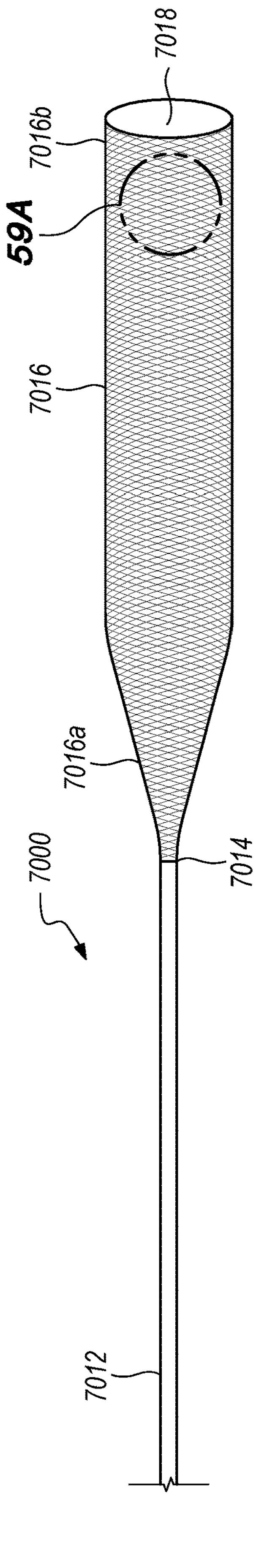


FIG. 59

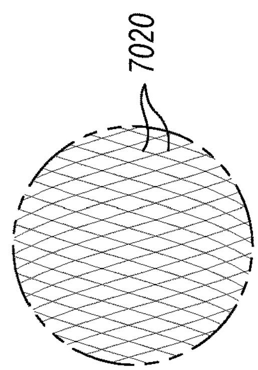


FIG. 59A

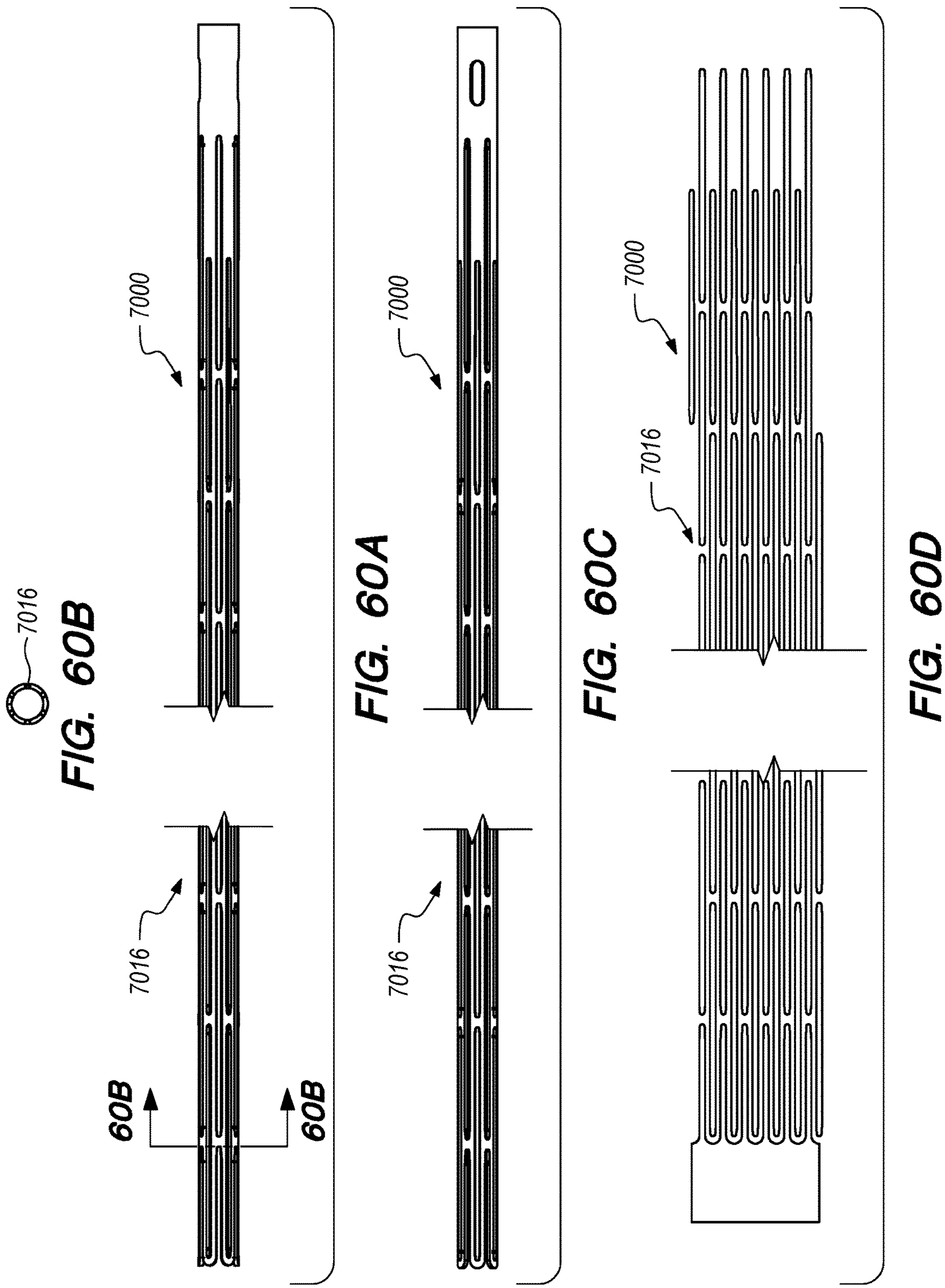


FIG. 60B

FIG. 60A

FIG. 60C

FIG. 60D

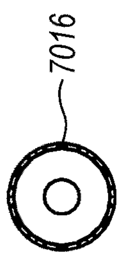


FIG. 61B

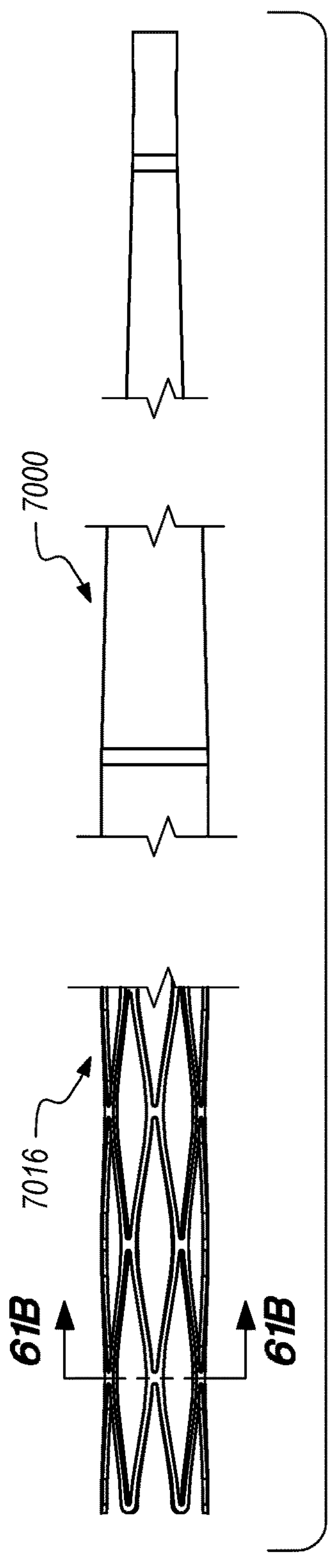


FIG. 61A

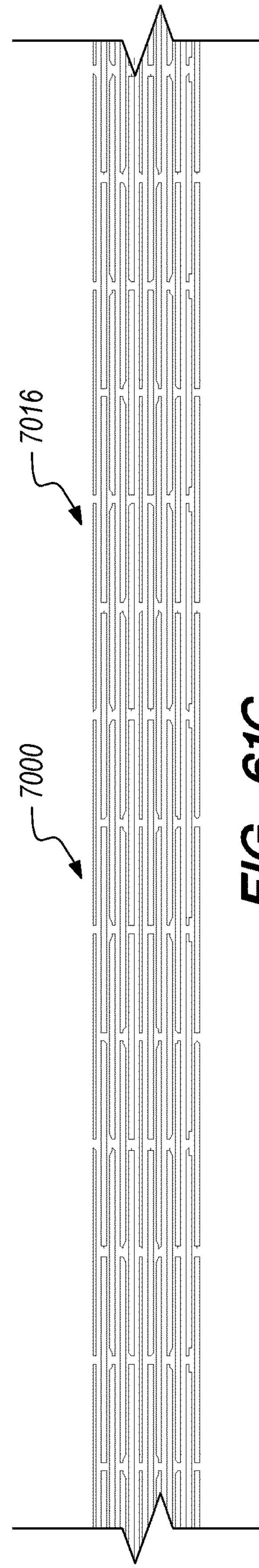


FIG. 61C

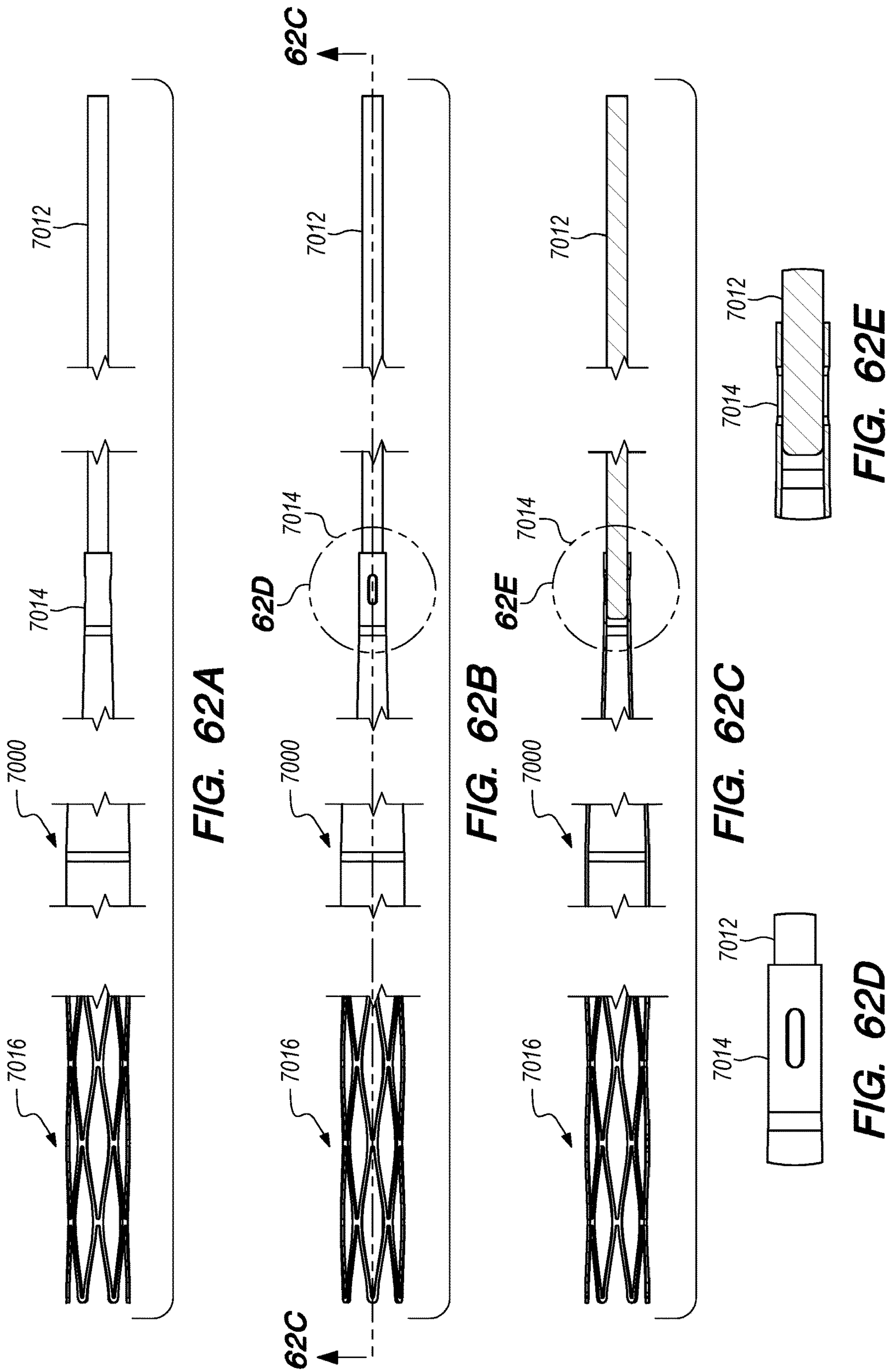


FIG. 62A

FIG. 62B

FIG. 62C

FIG. 62D

FIG. 62E

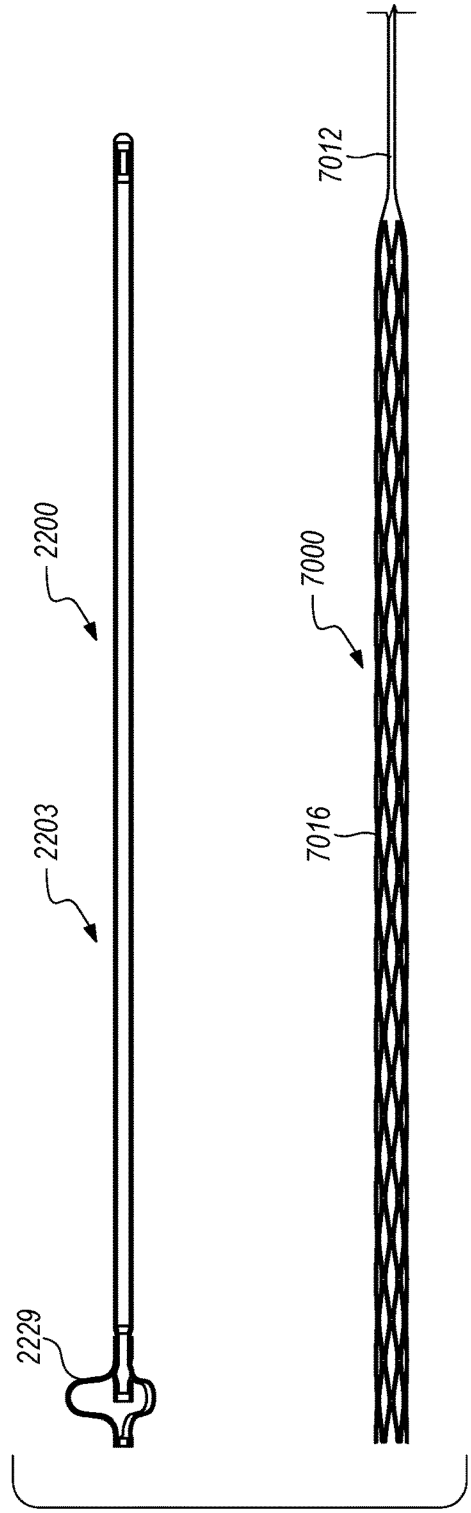


FIG. 63A

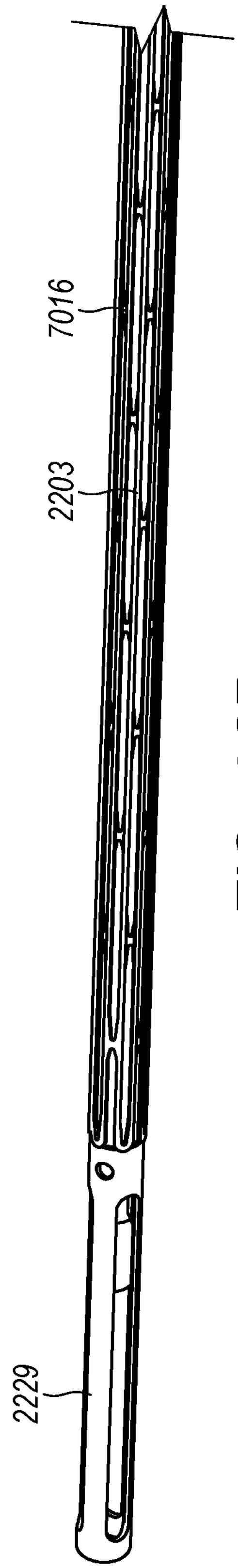


FIG. 63B

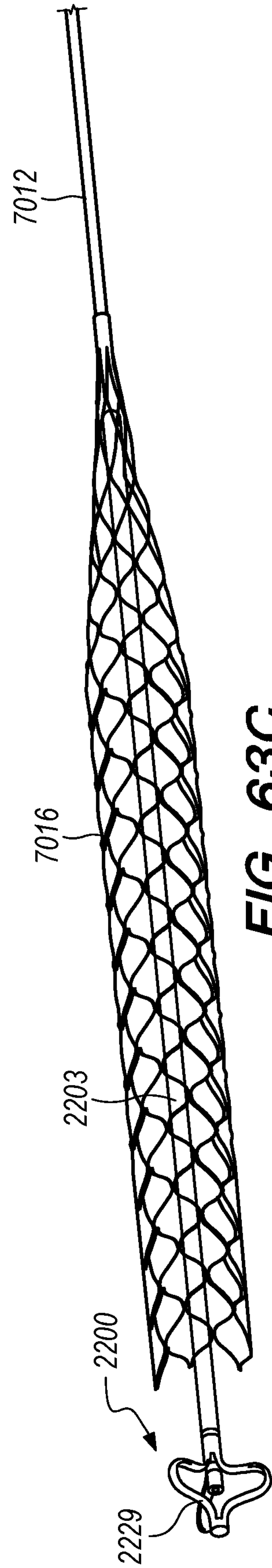
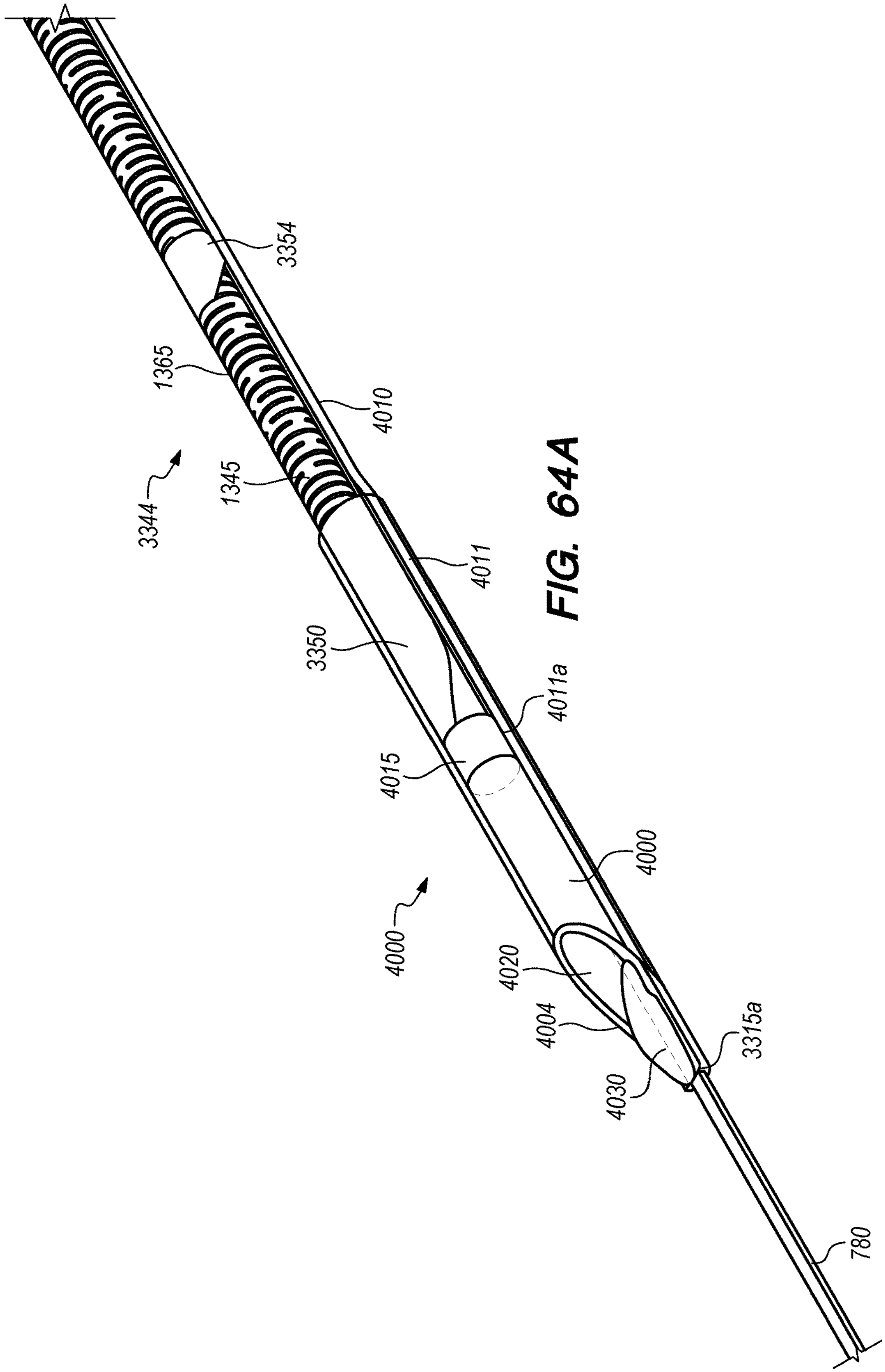


FIG. 63C


3354
1365
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3344
1345
4011
3350
4011a
4015
4000
4000
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4004
3315a
4030
780

FIG. 64A

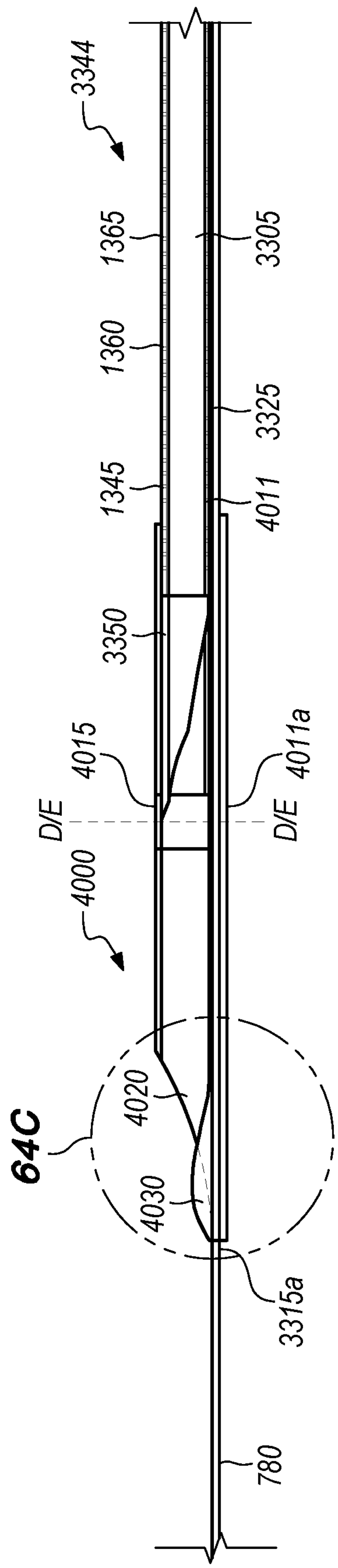

FIG. 64B

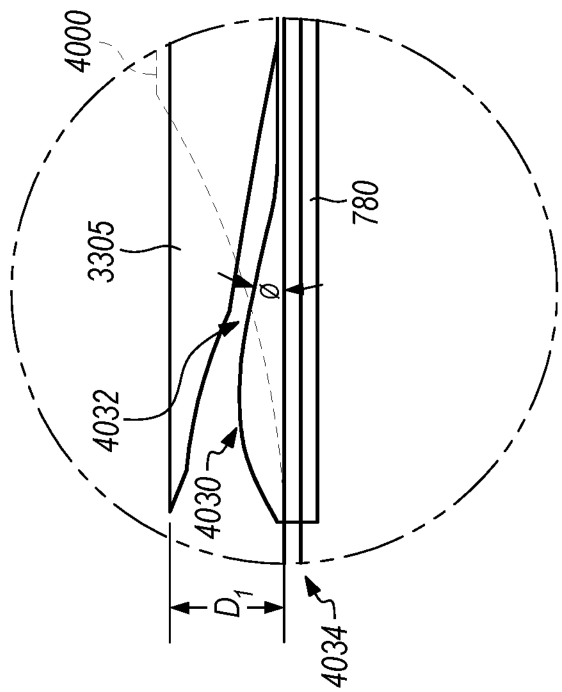

FIG. 64C

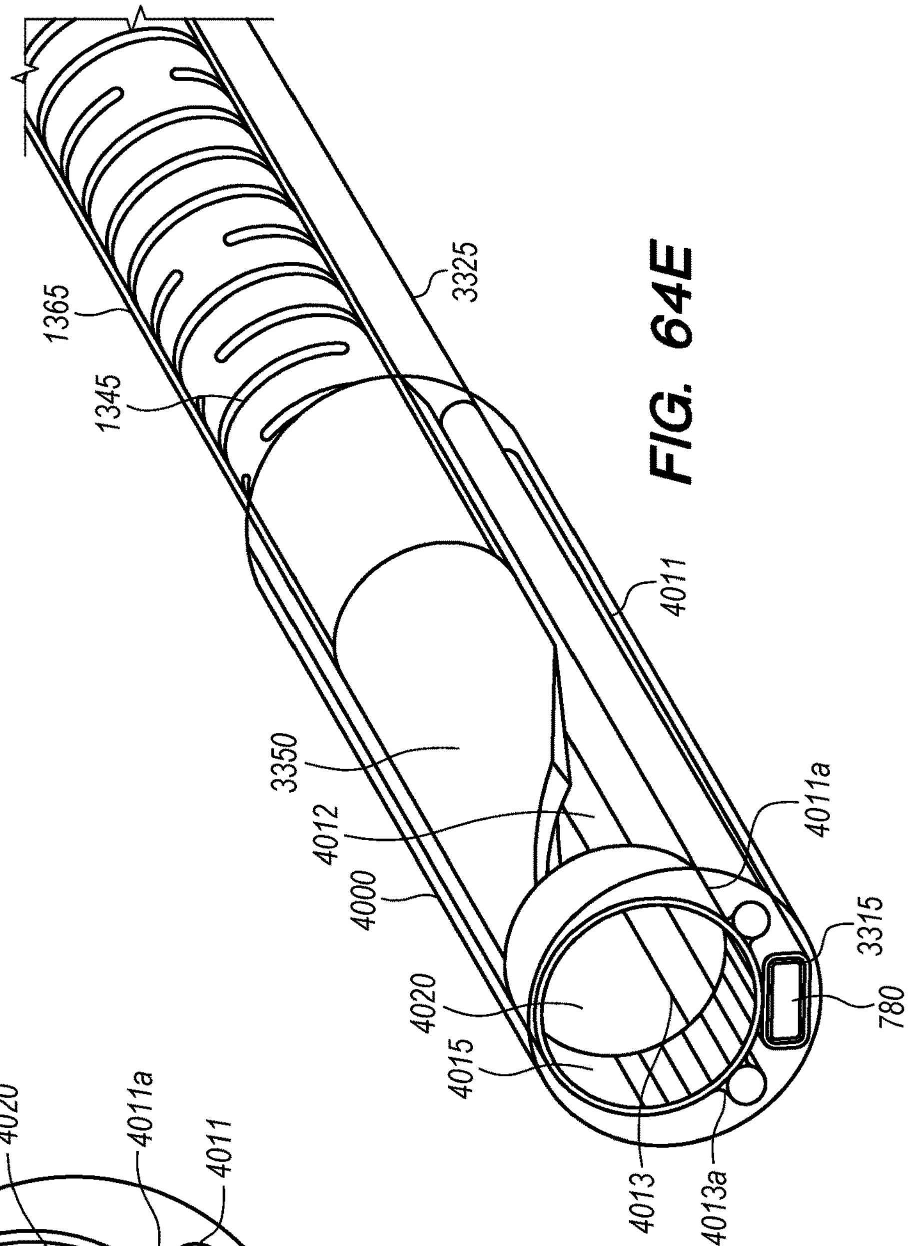

FIG. 64E

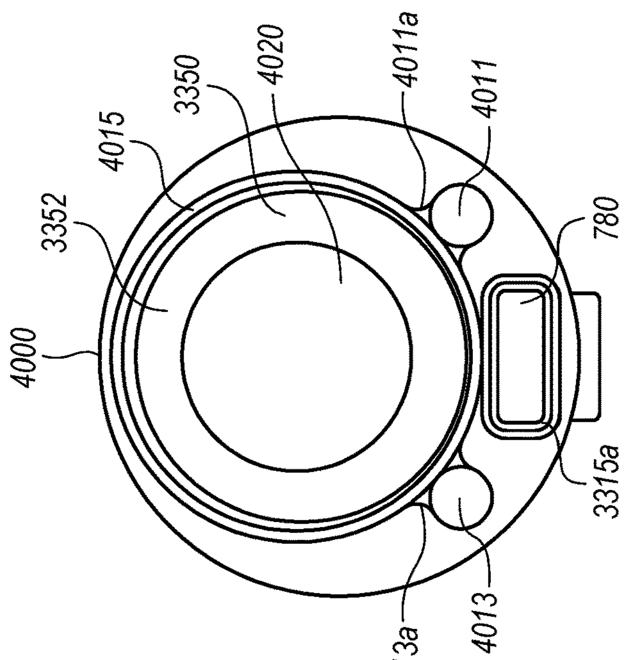

FIG. 64D

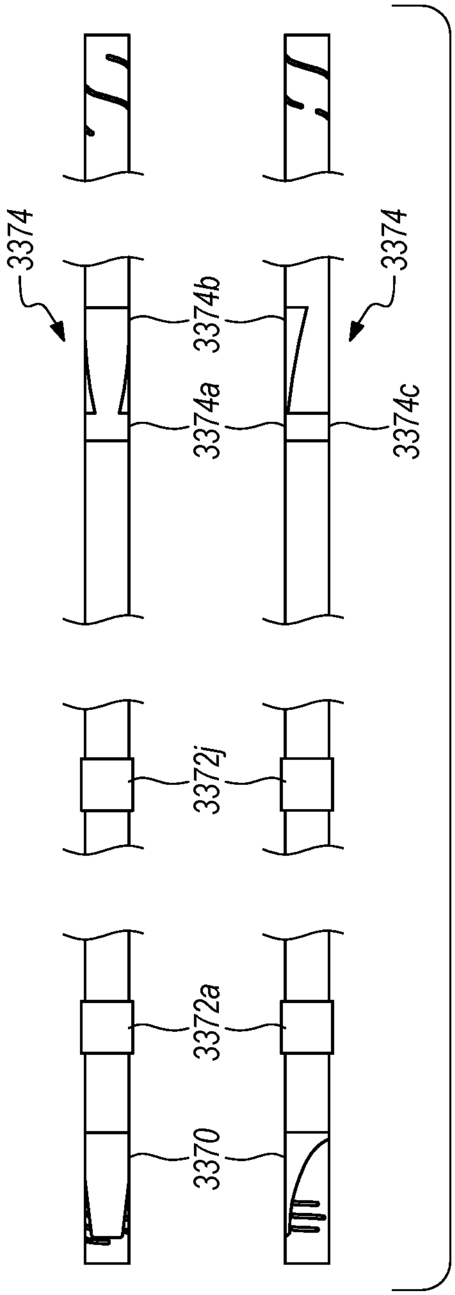

FIG. 65A

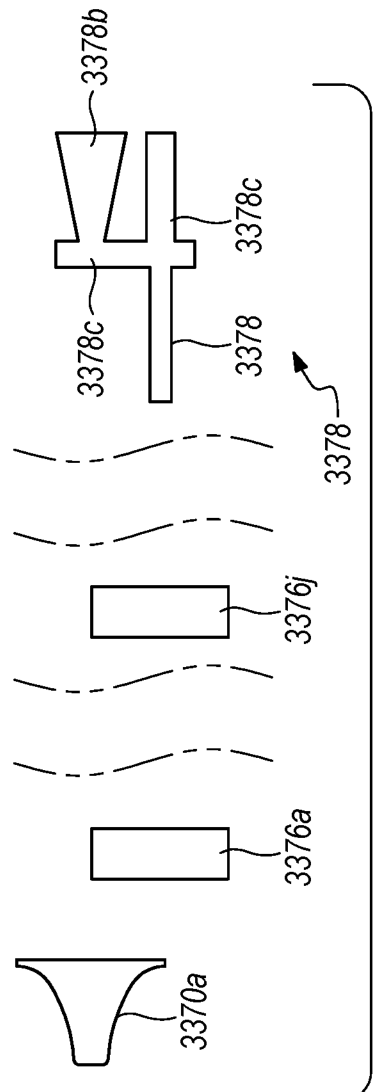

FIG. 65B

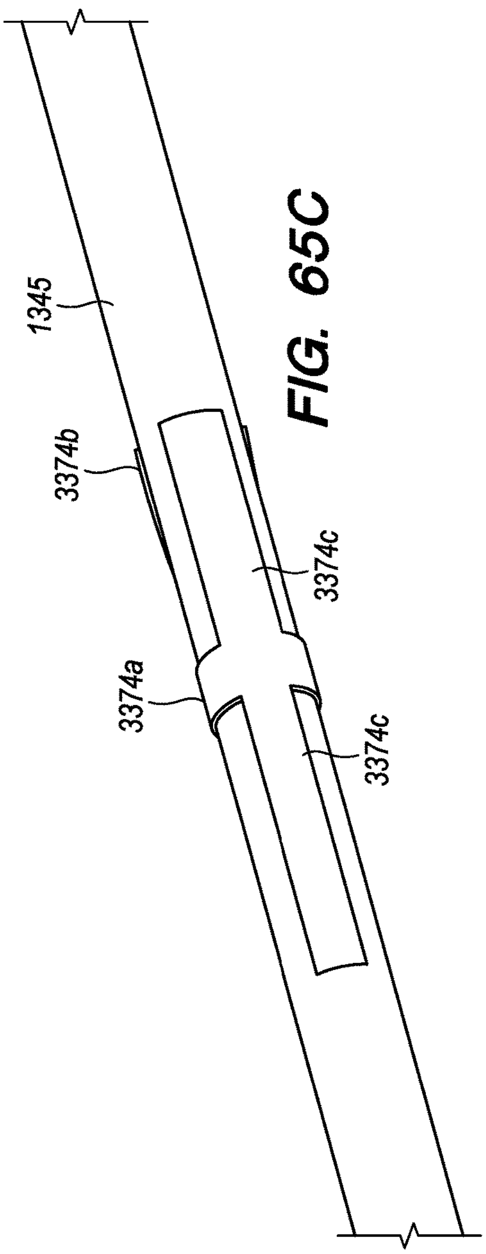

FIG. 65C

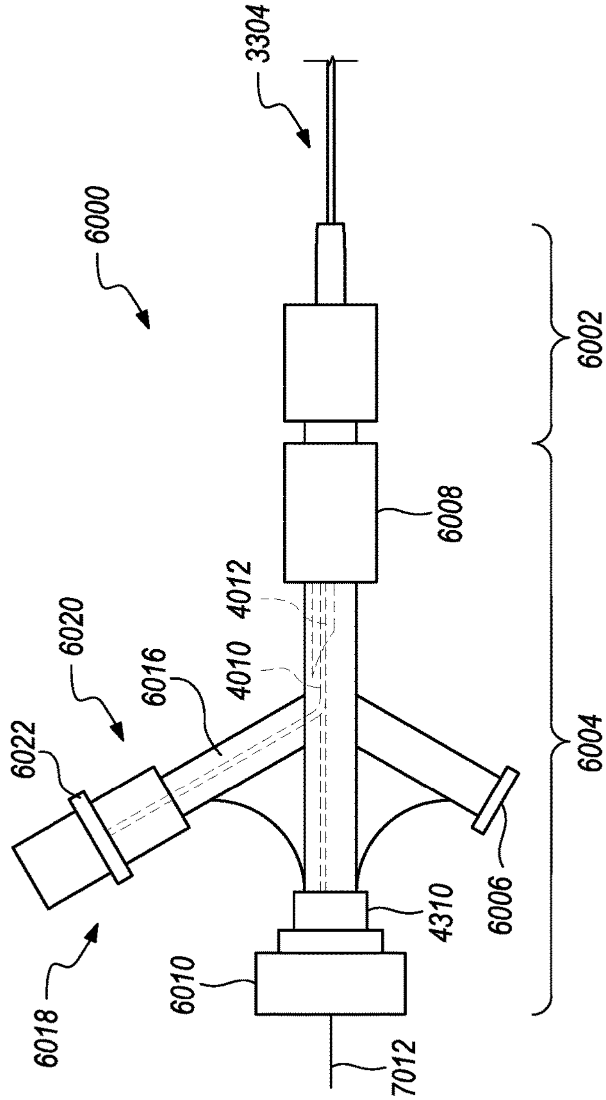

FIG. 66

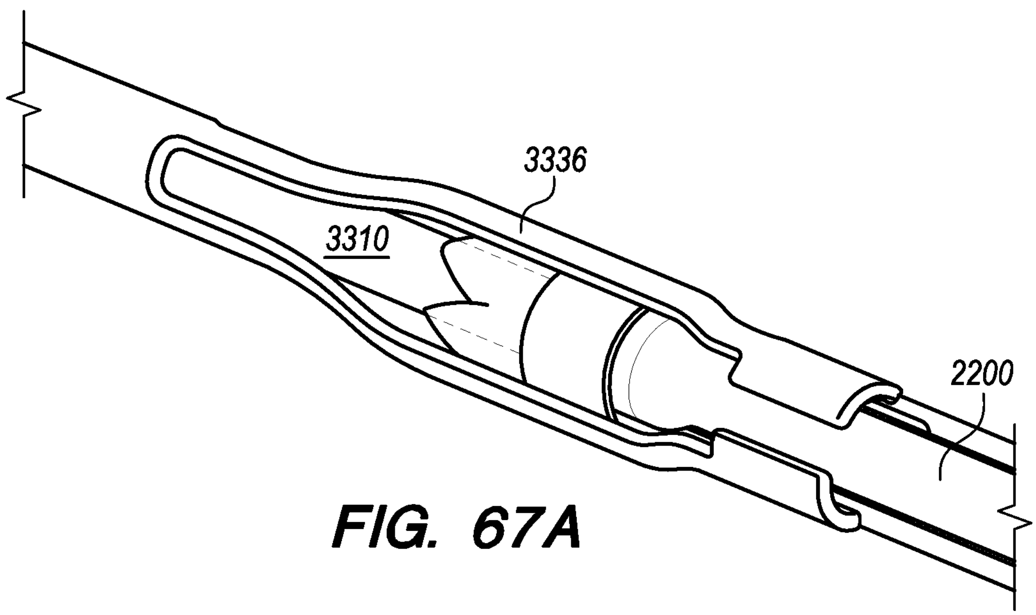

FIG. 67A

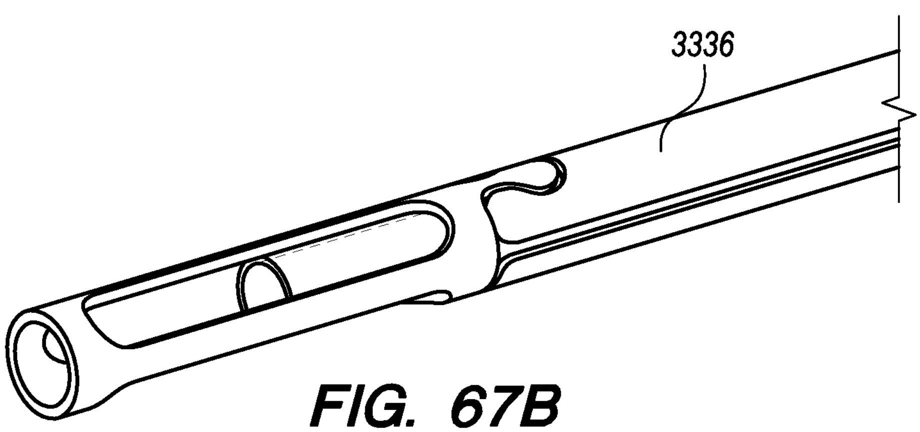

FIG. 67B

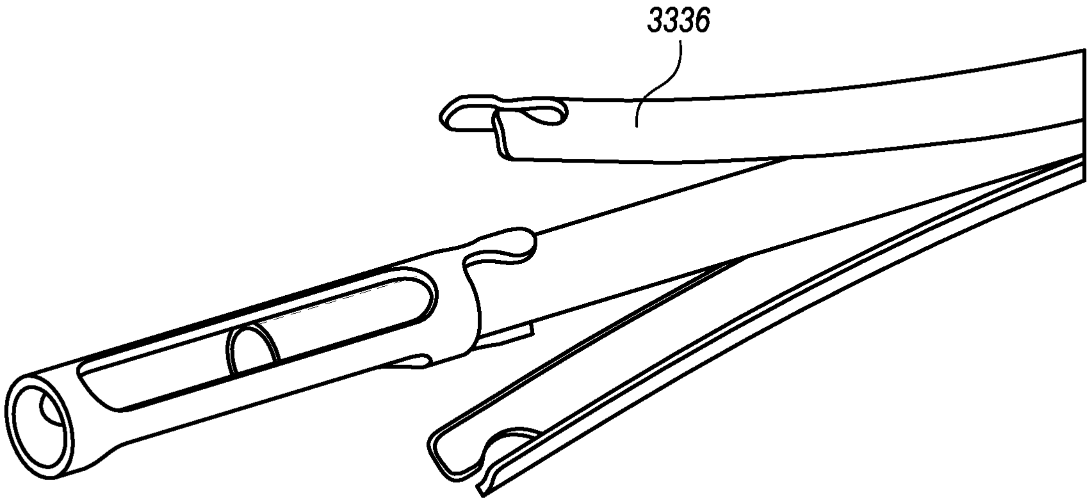

FIG. 67C

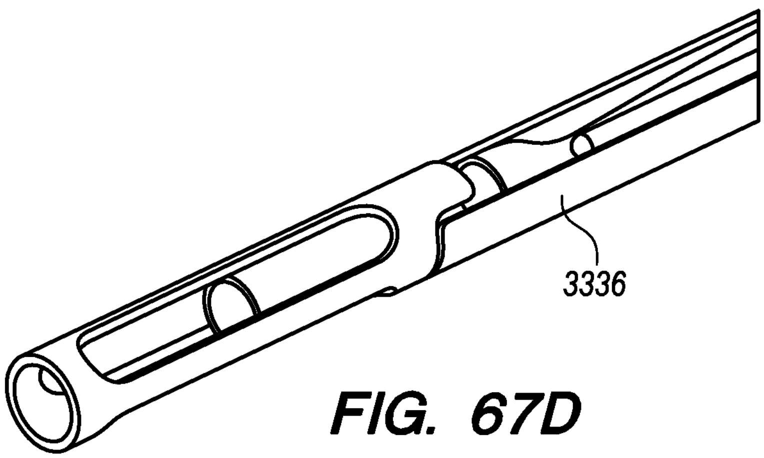

FIG. 67D

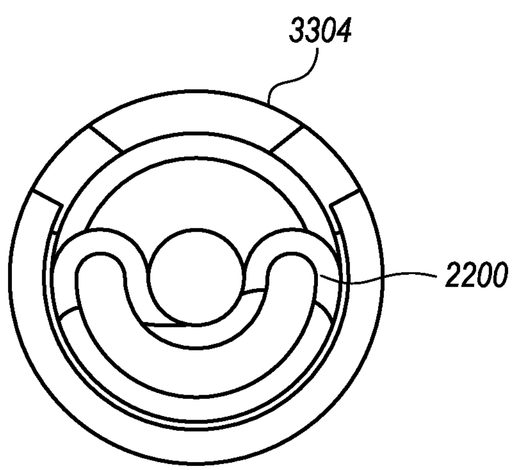

FIG. 67E

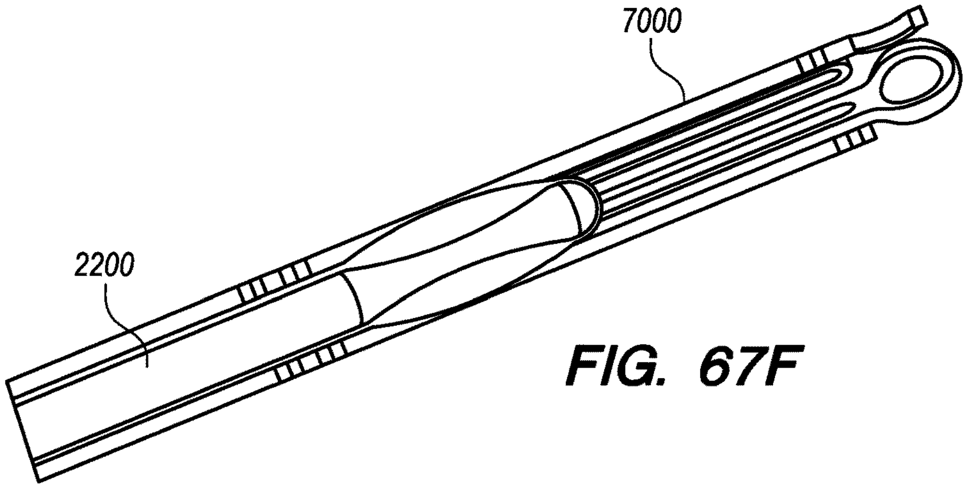

FIG. 67F

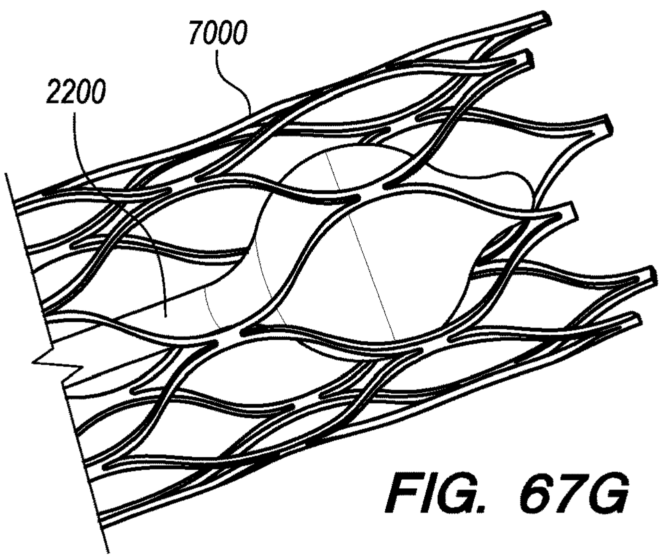

FIG. 67G

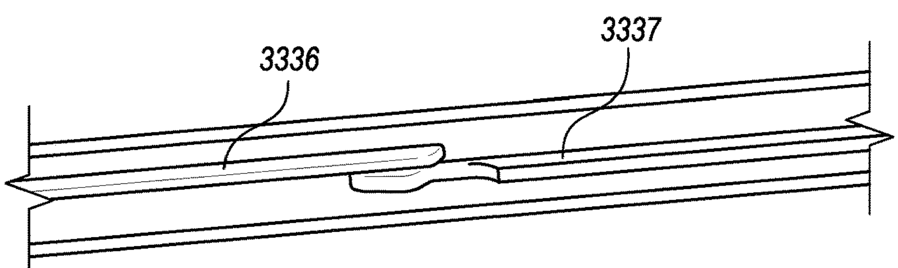

FIG. 67H

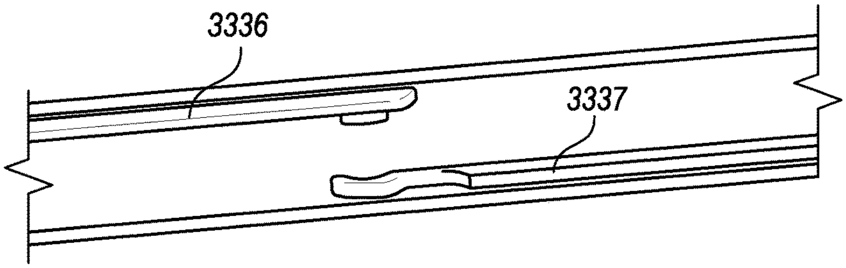

FIG. 67I

METHODS AND SYSTEMS FOR TREATING HYDROCEPHALUS

RELATED APPLICATION DATA

The present application is a National Phase entry under 35 U.S.C § 371 of International Patent Application No. PCT/US2017/056227, having an international filing date of Oct. 11, 2017, and which claims the benefit under 35 U.S.C. § 119 to U.S. provisional patent application Ser. Nos. 62/406,825, filed Oct. 11, 2016, and 62/473,729, filed Mar. 20, 2017, and also claims the benefit of priority under 35 U.S.C. § 120 to PCT Application serial number PCT/US2016/059592, having an international filing date of Oct. 28, 2016. The contents of the foregoing applications are hereby incorporated by reference into the present application in their entirety.

FIELD OF THE INVENTION

The inventions disclosed herein relate to systems and methods for accessing cerebral cisterns and draining cerebrospinal fluid (CSF), (e.g., to relieve elevated intracranial pressure), using an endovascular approach. More particularly, the present disclosure pertains to systems and methods for treatment of hydrocephalus, pseudotumor cerebri, and/or intracranial hypertension. The present application is related to U.S. patent application Ser. No. 14/929,066, filed on Oct. 30, 2015, which is hereby incorporated by reference into the present application in its entirety.

FIELD OF THE INVENTION

Background

Hydrocephalus is one of the most common and important neurosurgical conditions affecting both, children and adults. Hydrocephalus, meaning "water on the brain," refers to the abnormal CSF accumulation in the brain. The excessive intracranial pressure resulting from hydrocephalus can lead to a number of significant symptoms ranging from headache to neurological dysfunction, coma, and death.

Cerebrospinal fluid is a clear, physiologic fluid that bathes the entire nervous system, including the brain and spinal cord. Cells of the choroid plexus present inside the brain ventricles produce CSF. In normal patients, cells within arachnoid granulations reabsorb CSF produced in the choroid plexus. Arachnoid granulations straddle the surface of the intracranial venous drainage system of the brain and reabsorb CSF present in the subarachnoid space into the venous system. Approximately 450 mL to 500 mL of CSF is produced and reabsorbed each day, enabling a steady state volume and pressure in the intracranial compartment of approximately 8-16 cm H_2O. This reabsorption pathway has been dubbed the "third circulation," because of its importance to the homeostasis of the central nervous system.

Hydrocephalus occurs most commonly from the impaired reabsorption of CSF, and in rare cases, from its overproduction. The condition of impaired reabsorption is referred to as communicating hydrocephalus. Hydrocephalus can also occur as a result of partial or complete occlusion of one of the CSF pathways, such as the cerebral aqueduct of Sylvius, which leads to a condition called obstructive hydrocephalus.

A positive pressure gradient between the intracranial pressure of the subarachnoid space and the blood pressure of the venous system may contribute to the natural absorption of CSF through arachnoid granulations. For example in

non-hydrocephalic individuals, intracranial pressures (ICPs) can range from about 6 cm H20 to about 20 cm H20. ICP greater than 20 cm H20 is considered pathological of hydrocephalus, although ICP in some forms of the disease can be lower than 20 cm H20. Venous blood pressure in the intracranial sinuses and jugular bulb and vein can range from about 4 cm H20 to about 11 cm H20 in non-hydrocephalic patients, and can be slightly elevated in diseased patients. While posture changes in patients, e.g., from supine to upright, affect ICP and venous pressures, the positive pressure gradient between ICP and venous pressure remains relatively constant. Momentary increases in venous pressure greater than ICP, however, can temporarily disturb this gradient, for example, during episodes of coughing, straining, or valsalva.

Normal pressure hydrocephalus (NPH) is one form of communicating hydrocephalus. NPH patients typically exhibit one or more symptoms of gait disturbance, dementia, and urinary incontinence, which can lead to misdiagnosis of the disease. Unlike other forms of communicating hydrocephalus, NPH patients may exhibit little or no increase in ICP. It is believed that the CSF-filled ventricles in the brain enlarge in NPH patients to accommodate the increased volume of CSF in the subarachnoid space. For example, while non-hydrocephalic patients typically have ICPs ranging from about 6 cm H20 to about 20 cm H20, ICPs in NPH patients can range from about 6 cm H20 to about 27 cm H20. It has been suggested that NPH is typically associated with normal intracranial pressures during the day and intermittently increased intracranial pressure at night.

Other conditions characterized by elevated intracranial pressure include pseudotumor cerebri (e.g., benign intracranial hypertension). The elevated ICP of pseudotumor cerebri causes symptoms similar to, but that are not, a brain tumor. Such symptoms can include headache, tinnitus, dizziness, blurred vision or vision loss, and nausea. While most common in obese women 20 to 40 years old, pseudotumor cerebri can affect patients in all age groups.

Prior art techniques for treating communicating hydrocephalus (and in some cases, pseudotumor cerebri and intracranial hypertension) rely on ventriculoperitoneal shunts ("VPS" or "VP shunt" placement), a medical device design introduced more than 60 years ago. VPS placement involves an invasive surgical procedure performed under general anesthesia, typically resulting in hospitalization ranging from two to four days. The surgical procedure typically involves placement of a silicone catheter in the frontal horn of the lateral ventricle of the brain through a burr hole in the skull. The distal portion of the catheter leading from the lateral ventricle is then connected to a pressure or flow-regulated valve, which is placed under the scalp. A separate incision is then made through the abdomen, into the peritoneal cavity, into which the proximal portion of a tubing catheter is placed. The catheter/valve assembly is then connected to the tubing catheter, which is tunneled subcutaneously from the neck to the abdomen.

VPS placement is a very common neurosurgical procedure, with estimates of 55,000-60,000 VPS placements occurring in the U.S. each year. While the placement of a VP shunt is typically well-tolerated by patients and technically straightforward for surgeons, VP shunts are subject to a high rate of failure in treated patients. Complications from VP shunt placement are common with a one-year failure rate of approximately 40% and a two-year shunt failure rate reported as high as 50%. Common complications include catheter obstruction, infection, over-drainage of CSF, and intra-ventricular hemorrhage. Among these complications, infection is one of the most serious, since infection rates in adults are reported between 1.6% and 16.7%. These VPS failures require "shunt revision" surgeries to repair/replace a portion or the entirety of the VP shunt system, with each of these revision surgeries carrying the same risk of general anesthesia, post-operative infection, and associated cost of hospitalization as the initial VPS placement; provided, however that shunt infections can cost significantly more to treat (e.g., three to five times more) compared to initial VP shunt placement. Often these infections require additional hospital stays where the proximal portion of the VPS is externalized and long-term antibiotic therapy is instituted. The rate of failure is a constant consideration by clinicians as they assess patients who may be candidates for VPS placement. Age, existing co-morbidities and other patient-specific factors are weighed against the likelihood of VP shunt failure that is virtually assured during the first 4-5 years following initial VP shunt placement.

Despite significant advances in biomedical technology, instrumentation, and medical devices, there has been little change in the design of basic VPS hardware since its introduction in 1952.

SUMMARY

In accordance with one aspect of the disclosed inventions, an endovascular shunt implantation system is provided, the system including a guide member having a distal portion configured for being deployed in an inferior petrosal sinus (IPS) of a patient; a delivery catheter movably coupled to the guide member, wherein a distal end of the delivery catheter includes a tissue penetrating element, such that the delivery catheter and tissue penetrating element are translatable relative to the distal portion of the guide member within the IPS. The system further includes a guard is at least partially disposed over, and movable relative to, the tissue penetrating element. Optionally, an open distal end portion of the guard includes an inner surface feature configured to deflect the tissue penetrating element away from the guide member when the tissue penetrating element is translated distally relative to the guard. Optionally, the system further includes a shunt delivery shuttle at least partially positioned within a lumen of, and movable relative to, the delivery catheter, the shunt delivery shuttle comprising an elongate proximal pusher coupled to a distal shuttle portion made of mesh or a cut tube and configured to collapse around an elongate shunt body to thereby transport the shunt body through the delivery catheter lumen. The distal shuttle portion preferably self-expands to release the shunt body when the distal shuttle portion is advanced out of the delivery catheter lumen through the opening of the tissue penetrating element.

In exemplary embodiments, the system further includes an expandable anchor configured for being deployed in a dural venous sinus of the patient at a location distal to a target penetration site located on a curved portion of the IPS wall, wherein the elongate guide member is coupled to, and extends proximally from, the anchor. Optionally, the system further includes a guide member pusher tool configured for translating the respective guide member and anchor relative to the respective IPS and dural venous sinus (which may be the IPS). In various embodiments, the pusher tool comprises a handle having a lumen extending there through, and a tubular body portion coupled to the handle, the tubular body portion having a lumen that is contiguous with or otherwise extends through the handle lumen, the respective handle and tubular body lumens being configured to receive the guide member, wherein the handle is configured to allow selective engagement and release of a portion of the guide member extending proximally through the handle lumen for thereby pushing the guide member, and thus the anchor, distally.

In various embodiments, the guard includes a tubular guard body having a first guard body lumen or recess configured to receive the penetrating element, and a plurality of pull wires, each pull wire having a distal portion fixed within or otherwise attached to the guard body, wherein the pull wires are configured to translate the guard body proximally or distally relative to the delivery catheter so as to at least partially expose or cover, respectively, the penetrating element. The open distal end portion of the guard member preferably has a beveled or tapered portion, and wherein the inner surface feature is located on the beveled or tapered portion. In various embodiments, the inner surface feature of the guard member is formed by at least a partial bead of material applied to, or molded as part of, an inner surface of the guard member.

In various embodiments, the system further comprises an endovascular shunt device, which may also be provided separately from the system. The shunt device includes an elongate shunt body made out of a flexible unreinforced polyurethane-silicone blend or other polymer, and a distal shunt anchor coupled to a distal end of the shunt body, wherein the distal shunt anchor self-expands when advanced out of the delivery catheter lumen. The shunt device further includes one or more cerebrospinal fluid (CSF) intake openings in a distal portion of the shunt that are in fluid communication with a shunt lumen extending through the shunt body, the shunt body comprising one or more longitudinal slits configured to allow egress there through of CSF in the shunt lumen if a fluid pressure within the shunt lumen exceeds a body fluid pressure external of the one or more slits, and wherein a proximal end of the shunt body is fluidly sealed. In an exemplary embodiment, the shunt device includes a tubular connector having a proximal portion secured to a distal end of the shunt body, a distal portion secured to the distal shunt anchor, and an open distal end located within the distal shunt anchor, wherein the one or more CSF intake openings comprise a single CSF intake opening located in the distal end of the tubular connector. The tubular connector may be radiopaque or otherwise have one or more radiopaque elements coupled thereto. In some embodiments, the one or more longitudinal slits in the tubular body portion are configured and dimensioned to achieve a target flow rate of 5 ml of CSF per hour to 15 ml of CSF per hour through the CSF drainage lumen under normal differential pressure conditions between the CP angle cistern and venous system of the patient. In some embodiments, the one or more longitudinal slits in the tubular body portion are configured and dimensioned to allow CSF egress out of the CSF drainage lumen at a pressure differential between the CP angle cistern and the venous system of the patient in a range of 3 mm Hg to 5 mm Hg.

In accordance with another aspect of the disclosed inventions, a pusher tool is provided for deploying an elongate member (e.g., a solid guide wire or a hollow catheter) through a body lumen. In an exemplary embodiment, the pusher tool includes a handle having a lumen extending there through; and a tubular body portion coupled to the handle, the tubular body portion comprising a lumen that is contiguous with or otherwise extends through the handle lumen, the respective handle and tubular body lumens being configured to receive an elongate member there through, wherein the handle is configured to allow selective engagement and release of a portion of the elongate member extending proximally through the handle lumen for thereby pushing the elongate member distally. In a preferred embodiment, the handle comprises a proximal facing surface configured to mate with a human thumb or finger in order to selectively engage or release the elongate member using said thumb or finger.

In accordance with yet another aspect of the disclosed inventions, a method for deploying an elongate member (e.g., a guide wire or catheter) into a body lumen of a patient using the above-described pusher tool includes the steps of (a) inserting an elongate member through the respective handle and tubular body portion lumens of the pusher tool; (b) grasping the pusher tool (e.g., using a single hand); (c) pinching to thereby secure a portion of the elongate member against a proximal facing surface of the handle (e.g., using a finger or thumb of the same hand that is grasping the tool); (d) advancing the pusher tool while maintaining the pinched engagement of the elongate member against the handle surface so as to advance the elongate member distally into, or further into, the body lumen; (e) releasing the engaged portion of the elongate member from the handle surface; and (f) withdrawing the pusher tool proximally relative to the elongate member, wherein the method may further include repeatedly performing steps (c) through (f) until a distal end portion of the elongate member is positioned at a targeted location in the patient's body.

In instances in which the body lumen is a blood vessel, the elongate member is normally advanced into the blood vessel through an introducer sheath having a proximal opening outside of the patient and a distal opening within the blood vessel, in which case advancing the pusher tool may include advancing a distal portion of the tubular body into the proximal opening of the introducer sheath. The proximal opening of the introducer sheath is normally accessed via a proximal introducer hub, in which case the method may further include grasping to thereby stabilize the introducer hub while advancing the distal portion of the tubular body through the hub.

Other and further aspects and features of embodiments will become apparent from the ensuing detailed description in view of the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a head of a human patient;

FIG. **2**A-D are cross-sectional views of a portion of the head of a human patient;

FIG. **3**A-J are side, perspective and cross-sectional views of an anchor and elongate guide member, according embodiments of the disclosed inventions;

FIG. **4**A-C are perspective and cross-sectional views of an anchor and elongate guide member, according another embodiment of the disclosed inventions;

FIGS. **5**A-W are perspective and cross-sectional views of an anchor, according other embodiments of the disclosed inventions;

FIG. **6** is a side view of a delivery assembly according to embodiments of the disclosed inventions;

FIGS. **7**A-F are cross-sectional views of exemplary methods of delivering the anchor, the elongate guide member and the shunt at a target site, according embodiments of the disclosed inventions.

FIGS. **8**A-B are perspective and cross-sectional views of a delivery catheter, constructed according to embodiments of the disclosed inventions;

FIG. **9** is cross-sectional view of another delivery catheter, constructed according to another embodiment of the disclosed inventions;

FIGS. **10**A-J are perspective, side and cross-sectional views of a delivery catheter, according to another embodiment of the disclosed inventions;

FIG. **11** is a perspective view of an elongated member of the delivery catheter, constructed according to embodiments of the disclosed inventions

FIGS. **12**A-E are side, perspective and cross-sectional views of an elongated member of the delivery catheter, constructed according to other embodiments of the disclosed inventions;

FIG. **13** is a perspective view of an elongated pusher constructed according to embodiments of the disclosed inventions;

FIGS. **14**A-F are perspective views of exemplary methods for the elongated pusher of FIG. **13** use, according to embodiments of the disclosed inventions;

FIGS. **15**A-J are side, perspective and cross-sectional views of a shunt, constructed according to another embodiments of the disclosed inventions;

FIG. **16** is a cross-sectional views of an alternative delivery catheter, constructed according to embodiments of the disclosed inventions;

FIGS. **17**A-C are side, perspective and cross-sectional views of an elongated guide member, constructed according to an alternative embodiment of the disclosed inventions;

FIGS. **18**A-E are side, perspective and cross-sectional views of the interface between the elongated guide member and the anchor, according to embodiments of the disclosed inventions;

FIGS. **19**A-I are perspective and cross-sectional views of a delivery assembly having a penetrating element guard, according to embodiments of the disclosed inventions;

FIG. **20** is a side cross-sectional view of an penetrating element guard, constructed according to an alternative embodiment of the disclosed inventions;

FIGS. **21**A-M are side, perspective and cross-sectional views of a delivery catheter, constructed according to alternative embodiments of the disclosed inventions;

FIGS. **22**A-F are side, perspective and cross-sectional views of a shunt constructed according to embodiments of the disclosed inventions;

FIGS. **23**A-B are side, perspective and cross-sectional views of shunt, pusher member and catheter interface according to embodiments of the disclosed inventions;

FIGS. **24**A-F are side, perspective and cross-sectional views of shunt and pusher member interface according to embodiments of the disclosed inventions;

FIGS. **25**A-O are side, perspective and cross-sectional views of valves constructed according to embodiments of the disclosed inventions;

FIGS. **26**A-D are side, perspective and cross-sectional views of another valve constructed according to embodiments of the disclosed inventions;

FIGS. **27**A-D are side, perspective and cross-sectional views of yet another valve constructed according to embodiments of the disclosed inventions;

FIGS. **28**A-Q are side, perspective and cross-sectional views of valves constructed according to further embodiments of the disclosed inventions;

FIG. **29** is a perspective of another valve constructed according to embodiments of the disclosed inventions;

FIGS. **30**A-E are side, perspective and cross-sectional views of another shunt delivery catheter, constructed according to alternative embodiments of the disclosed inventions;

FIGS. **30**F-G are side and cross-sectional views of a reinforcing member of the shunt delivery catheter of FIGS. **30**A-E, constructed according to embodiments of the disclosed inventions.

FIGS. **31**A-G are perspective and side views of a marker constructed according to embodiments of the disclosed inventions;

FIG. **32** is a perspective view of an implanted shunt according to the embodiments of the disclosed invention;

FIGS. **33**A-**40**C are perspective and cross-sectional views of various embodiments of distal anchoring mechanisms of the shunt, constructed according to the embodiments of the disclosed invention;

FIGS. **41**A-**48**B are perspective and cross-sectional views of various embodiments of shunt bodies, constructed according to the embodiments of the disclosed invention;

FIGS. **49**A-**54**B are perspective and cross-sectional views of various embodiments of implanted shunts according to the embodiments of the disclosed invention;

FIGS. **55**A-O are perspective and cross-sectional views of exemplary methods for anchor delivery and shunt implantation procedures, according embodiments of the disclosed inventions;

FIGS. **56**A-**58**F are perspective, side and cross-sectional views of shunts constructed according to alternative embodiments of the disclosed inventions;

FIGS. **59**-**62**E are perspective and cross-sectional views of shunt delivery shuttles constructed according to embodiments of the disclosed inventions;

FIGS. **63**A-C are perspective views of a shunt and a shunt delivery shuttle interface according to embodiments of the disclosed inventions;

FIGS. **64**A-E are perspective and cross-sectional views of a penetrating element guard constructed according to alternative embodiments of the disclosed inventions;

FIGS. **65**A-C are side and perspective views of radiopaque markers constructed according to embodiments of the disclosed inventions;

FIG. **66** is perspective view of a handle assembly constructed according to embodiments of the disclosed inventions; and

FIGS. **67**A-I are side views of a shunt pusher constructed according to embodiments of the disclosed inventions.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

For the following defined terms, these definitions shall be applied, unless a different definition is given in the claims or elsewhere in this specification.

All numeric values are herein assumed to be modified by the term "about," whether or not explicitly indicated. The term "about" generally refers to a range of numbers that one of skilled in the art would consider equivalent to the recited value (i.e., having the same function or result). In many instances, the terms "about" may include numbers that are rounded to the nearest significant figure.

The recitation of numerical ranges by endpoints includes all numbers within that range (e.g., 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5).

As used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural referents unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

Various embodiments are described hereinafter with reference to the figures. The figures are not necessarily drawn to scale, the relative scale of select elements may have been exaggerated for clarity, and elements of similar structures or functions are represented by like reference numerals throughout the figures. It should also be understood that the figures are only intended to facilitate the description of the embodiments, and are not intended as an exhaustive description of the invention or as a limitation on the scope of the invention, which is defined only by the appended claims and their equivalents. In addition, an illustrated embodiment needs not have all the aspects or advantages shown. An aspect or an advantage described in conjunction with a particular embodiment is not necessarily limited to that embodiment and can be practiced in any other embodiments even if not so illustrated.

FIG. **1** is a schematic diagram showing the head **100** of a human patient. Within each side of the patient's head, an inferior petrosal sinus (IPS) **102** connects a cavernous sinus (CS) **104** to a jugular vein **106** and/or a jugular bulb **108**. For clarity, the acronym "IPS" is used herein to refer generally to the inferior petrosal sinus and more particularly to the interior space (or lumen) of the inferior petrosal sinus. The IPS **102** facilitates drainage of venous blood into the jugular veins **106**. In some patients, the junction of the IPS **102** and the jugular vein **106** occurs within the jugular bulb **108**. However, in other patients, this junction can occur at other locations in the jugular vein **106**. Moreover, while the IPS **102** in FIG. **1** is a single sinus passageway, in some patients the IPS can be a plexus of separate channels that connect the CS to jugular vein **106** (not shown) and/or jugular bulb **108**.

Embodiments of the disclosed inventions are described with respect to a target penetration site in the IPS **102** to access the CSF-filled CP angle cistern **138**, which provide a conduit for CSF to flow, via an implanted shunt device, from the subarachnoid space **116** into the jugular bulb **108**, jugular vein **106** (FIGS. **1**, **2**A-B) and/or the superior vena cava-right atrium junction (not shown). The delivery assemblies and shunts described herein can access the target penetration site in the IPS **102** through a venous access location in the patient. The delivery assemblies and shunts described herein can penetrate the dura mater IPS wall **114** and the arachnoid layer **115** to access the CP angle cistern **138** from within a superior petrosal sinus (SPS) **122** (FIG. **1**) for delivery and implantation of the shunt at the target site. The dura mater IPS wall **114** is also referred to herein as the dura IPS wall **114**, or simply as the IPS wall **114**. The SPS is a small diameter venous sinus that connects from the sigmoid sinus (distally located to jugular bulb **108**) to the cavernous sinus **104** (**1**). Further, the delivery assemblies and shunts described herein can be advanced through the IPS **102** and into the cavernous sinus **104**, so that an anastomosis (not shown) can be created in the upper portion or roof of the cavernous sinus **104** to access the CSP-filled suprasellar cistern **148**, shown in 1, for implantation of the shunt at such target site. Whether penetration to access a target site, deployment and implantation of a shunt occurs from the lumen of the SPS or cavernous sinus to access CSF in the subarachnoid space, the embodiments of the inventions described herein provide a conduit for CSF to flow from the subarachnoid space into the jugular bulb **108**, jugular vein **106**, and/or the superior vena cava-right atrium junction (not shown).

FIG. **2**A shows a cross-sectional view of a portion of head **100**, including IPS **102**, jugular vein **106**, and jugular bulb **108**. In addition, basilar artery **110**, brain stem **112**, pia **112***a*, and IPS wall **114** are also shown in FIG. **2**A. The IPS is a relatively small diameter intracranial venous sinus that facilitates drainage of cerebral venous blood into the jugular vein; the IPS is formed by a cylindrical layer of dura mater, typically about 0.9 mm to 1.1 mm thick for the portion of IPS wall **114** shown in FIG. **2**A, which creates a hollow lumen through which blood flows. In the cross-section view of FIG. **2**A, the hollow lumen of the IPS resides between upper IPS wall **114** and a lower IPS wall **117**, also comprised of dura mater; the IPS itself lies in a bony groove or channel in the clivus bone (not shown) beneath IPS wall **117** in FIG. **2**A.

A cross-section of the IPS **102** orthogonal to the plane depicted in FIG. **2**A would show that the cylindrical layer of dura mater forming IPS **102** is surrounded by bone for about 270° of its circumference with the remaining portion of the IPS circumference (i.e., IPS wall **114** in FIGS. **2**A-B) covered by arachnoid matter **115** and facing CP angle cistern **138**. Arachnoid mater **115** (also referred to herein as the arachnoid layer) is a delicate and avascular layer, typically about 0.05 mm to 0.15 mm thick, that lies in direct contact with the dura mater comprising the exterior of IPS wall **114**; arachnoid layer **115** is separated from the pia mater surrounding brain stem **112** by the CSF-filled subarachnoid space **116** (e.g., CP angle cistern **138**). The lower portion of the IPS **102**, opposite to the IPS wall **114** is the IPS wall **117** formed by dura mater that sits in a channel in the clivus bone (not shown).

It should be appreciated that for the embodiments of the disclosed inventions, the methods and devices are configured to create an anastomosis via an endovascular approach by piercing or penetrating from within the hollow IPS **102** to pass through the dura of IPS wall **114**, and continue penetrating through the arachnoid layer **115** until reaching the CSF-filled subarachnoid space **116** (e.g., CP angle cistern **138**). For ease of illustration, it should be appreciated that the arachnoid matter **115** covering the IPS wall **114** is present, although, not shown in certain figures.

The diameter d_1 of IPS **102** is approximately 3 mm but can range from approximately 0.5 mm to about 6 mm. As shown in FIG. **2**A, at the junction **118** between the IPS **102** and the jugular bulb **108** and/or jugular vein **106**, the diameter d_2 of the IPS **102** can narrow. For example, d_2 is approximately 2 mm, but can be as small as about 0.5 mm. The length of the IPS **102** from the junction **118** with the jugular vein **106** to the cavernous sinus **104** (shown in FIG. **1**) is approximately in a range between 3.5 cm to 4 cm.

In many patients, the IPS **102** is coupled to the jugular vein **106** at a location disposed below of the jugular bulb **108**, depicted as junction **118**, shown in FIG. **2**B. The IPS **102** extends distally from the junction **118** in the medial wall of the jugular vein **106**, past the 9th cranial nerve **111**A and jugular tubercle (not shown) while curving rostral-medially through a first curved portion **102**A shown in FIG. **2**C, and then further curving medial-superiorly through a second curved portion **102**B shown in FIG. **2**C before connecting at the connection point **111**B with the cavernous sinus (CS) **104**. The IPS **102** extends distally from the junction **118** through a curvature of approximately 45° to 100° in the first and second curved portions **102**A and **102**B until the IPS **102** connects with the CS **104**. The CSF-filled CP angle cistern **138** lies immediately above the curved portion of the IPS **102**.

Anatomical features of CP angle cistern **138** provide a large extent of unobstructed, CSF-filled subarachnoid space to accommodate a penetrating element and shunt distal anchoring mechanism as further described herein. FIG. **2**C shows a portion of CP angle cistern **138** and the relative proximity of the cistern to a patient's right IPS **102**R and left IPS **102**L. Beyond the lateral boundaries of the cistern depicted in the figure, the CSF filled subarachnoid space continues circumferentially around the base of the skull, albeit with a lesser extent of CSF space than in CP angle cistern **138**. CP angle cistern **138** comprises a depth of free CSF space labelled D**1** in FIG. **2**C between the skull base and brainstem (not shown, but, e.g., between the anterior portions of the occipital and spehnoid bones and the brain stem). CP angle cistern **138** also comprises a height of free CSF space labelled H**1** in FIG. **2**C that extends superiorly along the base of the skull (not shown, but extending superiorly from the jugular foramen). CP angle cistern **138** further comprises a width extent of free space labelled W**1** in FIG. **2**C (e.g., extent of free CSF space extending laterally between the right and left jugular foramina, not depicted). CP angle cistern **138** contains a relatively large volume of CSF, as defined by the exemplary depth D**1**, height H**1**, and width W**1** dimensions. FIG. **2**D shows an alternative view of the same patient anatomy depicted in FIG. **2**C, albeit with the D**1** cistern dimension portions of left IPS **102**L obscured by the view.

As shown in FIGS. **1** and **2**C, most patients have two IPS **102** and two jugular veins **106** (left and right). In a very small percentage of patients (e.g., less than 1%), there is no connection between one IPS and the corresponding jugular vein. It is highly unlikely, however, that any given patient will lack connections to the corresponding jugular veins on both left and right IPS.

Subarachnoid spaces are naturally occurring separations between the pia mater and the arachnoid layer where the CSF pools. Typically, the CSF is passed into a subarachnoid space over the cerebral hemispheres and then into the venous system by arachnoid granulations. The subarachnoid space **116** in FIG. **2**A corresponds to a cerebellopontine (CP) angle cistern **138**, which acts as a reservoir for CSF. In patients with hydrocephalus, a build-up of CSF within the CP angle cistern **138** (in addition to other cisterns and the brain ventricles) can occur, for example, if patients lack properly functioning arachnoid granulations. If the excess CSF is not removed, the resulting excess intracranial pressure can lead to symptoms such as headache, neurological dysfunction, coma, and even death.

FIGS. **3**A-J illustrates exemplary anchor **700**, according to the embodiments of the disclosed inventions. The anchor **700** comprises a proximal portion **740**, a middle or body portion **730**, a distal portion **720** (FIG. **3**A), and a lumen **750** extending therebetween (FIG. **3**A-B). The proximal portion **740** of FIGS. **3**A, **3**C, **3**E, **3**F includes a beveled or tapered proximal section **742**. The anchor **700** further comprises an elongate guide member **780** coupled to the proximal portion **740** and/or beveled/tapered proximal section **742**. As shown in FIGS. **3**A, **3**C and **3**F, the beveled/tapered proximal section **742** is offset, as the taper transitions to the bottom of proximal portion **740** and the elongate guide member **780**. Alternatively, the beveled/tapered proximal section **742** may be symmetrical having the elongate guide member **780** centrally disposed, as shown in FIGS. **3**E and **3**H. Additionally, the distal portion **720** of the anchor **700** may include a beveled/tapered distal section **742**, as shown in FIG. **3**F. The proximal portion **740** and distal portion **720** of the anchor **700** may taper at a variety of suitable angles. The proximal portion **740** of the anchor **700** may comprise a strut or plurality of struts **712** directly or indirectly coupled to the elongate guide member **780** (e.g., FIG. **3**E, **3**H). In an alternative embodiment, the anchor **700** proximal portion

740 and distal portion 720 terminates at approximately 90° angle (i.e., without tapering), as shown in FIG. 3G.

The anchor 700 may be composed of suitable materials, such as, platinum, Nitinol®, gold or other biocompatible metal and/or polymeric materials, for example, silicon, or combinations thereof. In some embodiments, the anchor 700 may include materials that are compatible with magnetic resonance imaging and have radiopacity sufficient to allow the use of known imaging techniques. In some embodiments, the anchor 700 is composed of shape memory, self-expandable and biocompatible materials, such as Nitinol®, or other super-elastic alloys, stainless steel, or cobalt chromium, and comprises a stent-like configuration. In other embodiments, the anchor 700 may include other suitable configurations, such as tubular prosthesis, flow diverter, clot retriever, or the like. Alternatively, the anchor 700 can be composed of magnesium, zinc, or other bio-absorbable or dissolvable components.

The anchor 700 may be formed by laser cutting a flat sheet, a tubular member, or other suitable configuration of the described materials into interconnected struts 712 forming an open or closed cell pattern having a plurality of cells 714, as shown by the closed cell patterns in FIGS. 3A and 3C-H. Detailed portions of exemplary closed cell patterns of the anchor 700 having the plurality of struts 712 defining the plurality of cells 714 are shown in FIGS. 3I-J. Other suitable techniques may be used to form the closed (or open) cell pattern of the anchor 700, such as etching, or having a plurality of wires braided, woven, or coupled together (not shown). The anchor 700 further comprises a radially collapsed or delivery configuration and, a radially expanded or deployed configuration. In the deployed configuration the anchor 700 is configured to radially expand and anchor itself within the IPS 102 or CS 104. The anchor 700 may include a length L_1 of approximately 2 mm to approximately 20 mm, in the radially expanded configuration (FIG. 3C). The anchor 700 may include an outer diameter OD_1 of approximately 2 mm to approximately 6 mm or larger, in the radially expanded configuration (FIG. 3D). The anchor 700 is radially compressible about the axis 751 of the lumen 750, and configured to collapse within a delivery catheter (e.g., a delivery catheter having an inner diameter of approximately 0.014" to approximately 0.040") such that a clinician can navigate the collapsed anchor 700 through one or more catheters into the IPS 102 or CS 104.

The anchor 700 and the elongate guide member 780 coupled to the proximal portion 740 of the anchor 700 can be manufactured from the same piece of material (e.g., a super-elastic alloy such as Nitinol®), or may comprise separate parts joined at a joint 744 between anchor 700 and the elongate guide member 780. As shown in FIGS. 3A, 3C, 3E-H, the elongate guide member 780 is coupled (e.g., directly or indirectly, attached, secured, joined, or their like) to the proximal portion 740 of the anchor 700. Alternatively, the elongate guide member 780 can be coupled to the distal portion 720, middle portion 730, and/or to any strut or plurality of struts 712 (FIG. 3E, 3H) of the anchor 700 (not shown). The elongate guide member 780 can have a flat, rectangular, or otherwise non-circular, cross-sectional profile, as shown for example in FIG. 3D and FIG. 11. By way of non-limiting example, the elongate guide member 780 can have a rectangular cross-sectional profile with dimensions of approximately 0.001"×0.003" to 0.008"×0.040". An elongate guide member 780 with rectangular cross-sectional profile can provide increased column strength to facilitate navigation of the anchor 700 through a delivery catheter to a target location in IPS 102 or CS 104 and, if necessary, to assist with the re-sheathing of the anchor 700 into a delivery catheter for re-deployment of the anchor 700 prior to penetration of the IPS wall 114/arachnoid layer 115 and deployment of the shunt, or when removing the anchor 700 from the patient's vasculature after the deployment of the shunt. When used with the delivery catheter 3304 including a dedicated lumen 3315 configured to conform to the rectangular cross-sectional profile of the guide member 780 (e.g., as shown in FIG. 10), the elongate guide member 780 maintains the trajectory of the delivery catheter 3304 over the guide member and at the target penetration site by limiting or preventing rotation of the delivery catheter 3304 about or around the guide member 780.

Alternatively, embodiments of elongate guide member 780 can have a circular cross-sectional profile, as shown in FIGS. 17A-C. By way of non-limiting example, an elongate guide member 780 with circular cross-sectional profile can have a diameter of about 0.005" to 0.018" or more. The elongate guide member 780 having a tubular configuration may include a plurality of cuts to increase flexibility, as shown by the exemplary spiral cut pattern of kerf, pitch, cuts per rotation and cut balance depicted in sections of FIGS. 17A-C. Such configurations of the elongate guide member can improve the "trackability" of a delivery catheter over the guide member (e.g., a delivery catheter with a dedicated lumen configured to conform to the guide member profile), and provide the ability to radially orient the delivery catheter and penetrating element about the guide member in the lumen of IPS 102 or CS 104. An elongate guide member 780 with circular cross-sectional profile can provide increased column strength to facilitate navigation of the anchor 700 through a delivery catheter to a target location in IPS 102 or CS 104 and, if necessary, to assist with the re-sheathing of the anchor 700 into a delivery catheter for re-deployment of the anchor 700 prior to penetration of the IPS wall 114/arachnoid layer 115 and deployment of the shunt, or when removing the anchor 700 from the patient's vasculature after the deployment of the shunt. Further, the ability to radially orient the delivery catheter and penetrating element about the guide member in the lumen of IPS 102 or CS 104 can be used to correct the orientation of a mis-loaded delivery catheter over the guide member.

The profile, dimensions, and material for the elongate guide member 780 are configured to resist kinking along the length of the elongate guide member 780 and provide sufficient column strength for anchor deployment and re-sheathing, while still allowing sufficient flexibility for deployment through a delivery catheter by tracking through the curved portion of the IPS 102. Alternatively, the elongate guide member 780 can have a pre-curved distal portion, disposed closer to the joint 744 between anchor 700 and the elongate guide member 780, so as to bias the elongate guide member 780 towards IPS wall 114 or IPS wall 117 when the elongate guide member 780 is deployed through the curved portion of the IPS 102. Further, the joint 744 between the anchor 700 and the elongate guide member 780 may include a rotatable element (FIGS. 18E-F) allowing the elongate guide member 780 to assume a desirable orientation through the curved portion of the IPS 102.

Radiopaque markings or coatings can be incorporated into the anchor 700 and/or elongate guide member 780 to assist with navigation and deployment of the anchor 700 in a sinus lumen distal to a target penetration site on IPS wall 114. The radiopaque markings may be placed on one or more of the following locations along the anchor 700 and elongate guide member 780, as shown in FIG. 3C: in a plurality of struts 712 at the distal portion 720 of the anchor 700; along L_1, with or without rotationally varying marker placement along the middle or body portion **730** of the anchor **700** to further aid navigation and orientation; at the joint **744** between anchor **700** and the elongate guide member **780**, and/or on or around the first full-diameter portion of anchor **700** at the proximal portion **740**.

FIGS. **4**A-C illustrate another exemplary anchor **700**, constructed according to embodiments of the disclosed inventions. FIG. **4**A-B depict respective side views, and FIG. **4**C depicts a cross-sectional view of the anchor **700**, comprising a plurality of cuts **710** forming a stent-like configuration, having a plurality of struts **712**. The anchor **700**, the elongate guide member **780**, cuts **710** and/or the patterns of the cuts **710** may be manufactured by selectively cutting a tubular element using any suitable cutting method (e.g., laser cutting, etching or their like). FIGS. **5**A-W depicts exemplary dimensions and cut patterns of the anchor **700**, constructed according to embodiments of the disclosed inventions. The struts **712** of the anchor **700** form a plurality of spaces or cells **714** therebetween. The cells **714** include a closed cell pattern when the anchor **700** is in the radially expanded configuration, as for example shown in FIGS. **3**E, **3**H-J, **5**O and **5**U, and a closed cell pattern when the anchor **700** is in the radially compressed configuration, as for example shown in FIGS. **4**A, **5**G, and **5**K. In one embodiment of the anchor **700**, the cut pattern shown in the radially compressed configuration in FIG. **5**G, is configured to form the radially expanded configuration of the anchor **700** shown in FIG. **5**O. FIGS. **5**P-T illustrate exemplary dimensions and properties of the anchor **700** of FIGS. **5**G and **5**O, such as the variations of the beveled/tapered proximal portions **740**. Varying the taper in the proximal portion **740** (e.g., as described by the transition length measurements of FIG. **5**T) can facilitate smooth anchor deployment and retrieval when paired with an appropriately sized catheter (e.g., catheter with 0.027" inner diameter). In an alternative embodiment of the anchor, the cut pattern shown in the radially compressed configuration in FIG. **5**K, is configured to form the radially expanded configuration of the anchor **700** shown in FIG. **5**U. FIGS. **5**V-W illustrate exemplary dimensions and properties of another embodiment of anchor **700** of FIG. **5**U, such as having beveled/tapered proximal portion **740** and distal portion **720**. The beveled/tapered distal portion **720** of anchor **700** depicted in FIG. **5**U, and corresponding flexibility provided by the spiral cut pattern of such distal portion shown in FIG. **5**K, facilitates access to remote, narrowing, and/or tortuous regions of the intracranial venous anatomy such as IPS **102** and CS **104**. For illustration purposes, FIGS. **5**P-S and **5**V-W are depicted without the struts **712** and cells **714** of the anchor **700** to better appreciate the dimensions and properties of the anchor **700** in said figures (in a radially expanded configuration). However, it should be appreciated that the anchor **700** of FIGS. **5**P-S and **5**V-W includes the struts **712** and cells **714** of their respective FIGS. **5**O and **5**U The struts **712** and cells **714** of the anchor **700** substantially extend along the length L_1, as for example shown in FIG. **3**C in the radially expanded configuration, and in FIG. **5**G in the radially compressed configuration. However, the struts **712** and cells **714** may extend along selected portions of the anchor **700**, as for example shown in FIG. **5**U at the distal portion **720**. Additionally, the anchor **700** can include a mesh framework between the struts **712** to increase the friction between the anchor **700** and IPS **102** (or CS **104**), further securing the anchor **700** at or about the target site when deployed. The struts **712** of anchor **700** can have flat, round, elliptical, or irregularly shaped profiles or suitable cross-sections. The width of the struts **712** can vary from approximately 0.0030" to 0.0045", or larger. Additionally, the struts **712** can be configured to exhibit a negative Poisson's ratio under strain such that, after deployment in a sinus lumen (e.g., IPS **102** or CS **104**), applying a retrograde force to anchor **700** (e.g., by pulling proximally on the anchor **700** via the elongate guide member **780**) further expands the struts **712** radially outward to secure the anchor **700** at the target site.

Dimensions referenced in FIGS. **5**A-**5**W in brackets (e.g., [14.67]) are provided in millimeters, while all other dimensions referred without brackets are provided in inches. It should be appreciated that the dimensions depicted in FIGS. **4**A-**5**W are exemplary dimensions of the anchor **700**, which are not intended to limit the embodiment of the anchor **700** disclosed herein.

FIG. **6** is a side view of a delivery assembly **300** for delivering the anchor **700** and the shunt into a target site of a patient, constructed in accordance with embodiments of the disclosed inventions. The delivery assembly **300** includes the anchor **700** and the shunt (not shown) detachably coupled to the delivery assembly **300**. The delivery assembly **300** and the shunt may be composed of suitable biocompatible materials. The delivery assembly **300** is dimensioned to reach remote locations of the vasculature and is configured to deliver the anchor **700** and the shunt percutaneously to the target location (e.g., inferior petrosal sinus). The delivery assembly **300** includes a tubular member interface having an outer tubular member **320** (i.e., guide catheter) and an inner tubular member **304** (i.e., delivery catheter/micro catheter) coaxially disposed within the outer tubular member **320** and movable relative to the outer tubular member **320**. The delivery assembly **300** may include a guidewire **302** coaxially disposed within the guide catheter **320** and/or the delivery catheter **304**. The guidewire **302** can be, for example, 0.035" (0.889 mm) in diameter. Additionally to the guidewire **302**, the delivery assembly **300** may include a delivery guidewire **308** disposed within the delivery catheter **304**. The delivery guidewire **308** has a smaller diameter (e.g., approximately 0.010" (0.254 mm) to 0.018" (0.4572 mm) or other suitable dimension to facilitate accessing intracranial venous vasculature with other components of delivery assembly **300**) compared to guidewire **302**.

The guide catheter **320**, delivery catheter **304**, and guidewires **302**/**308** (FIG. **6**) may be formed of suitable biocompatible materials, and may include markings **13** for purposes of imaging (e.g., markers composed of radio-opaque materials). Various known and often necessary accessories to the delivery assembly **300**, e.g., one or more radiopaque marker bands **13** at the distal portion **324** of the guide catheter **320** to allow viewing of the position of the distal portion under fluoroscopy and a Luer assembly **17** for guidewires and/or fluids access, are shown in FIG. **6**. The delivery assembly **300** and/or the shunt may include a penetrating element (not shown) configured to pierce and/or penetrate the IPS wall **114** and arachnoid layer **115** to access the CP angle cistern **138** for implantation of the shunt **200**.

FIGS. **7**A-F illustrate exemplary methods of delivering the anchor **700**, the elongate guide member **780** and the shunt **200** at a target site, according embodiments of the disclosed inventions. The anchor **700** is configured to be deployed and disposed within the IPS **102** or the CS **104** prior to penetration of the IPS wall **114** and deployment of a shunt. In some embodiments, the anchor **700** is configured to be distally disposed to a target penetration site in IPS wall **114**, as to provide support (e.g., foundation) for subsequent IPS wall **114** penetration, and shunt deployment steps of the implant procedure. The anchor **700** may be deployed in the IPS **102** or CS **104** by advancing the anchor **700** out of the distal end opening of the delivery catheter **304**, or by withdrawing the delivery catheter **304**, and/or by a combination of advancing the anchor **700** and withdrawing the catheter **304** for deployment of the anchor **700** in the IPS **102** or CS **104** (not shown).

When the anchor **700** is deployed into the target site (e.g., IPS **102** or CS **104**), the anchor **700** transitions from its delivery configuration (e.g., radially constrained by an inner lumen of the delivery catheter **304**) to its deployed configuration (e.g., expanding radially outwards, so as to engage the walls of the IPS **102** or CS lumen **131**). When deployed (FIG. **7**A), the struts **712** of the anchor **700** are biased to exert an outward radial force that engages and secures the anchor **700** within the IPS **102**, against IPS walls **114** and **117**, or against the equivalent walls of the CS **104**. The ratio of the resting anchor **700** diameter (i.e., expanded, unconstrained configuration) to the reference vessel diameter (i.e., diameter of the sinus lumen where the anchor will be deployed) can range from about 1:1 up to about 2:1. In addition, the exterior surface of anchor **700** can include anchoring elements, spikes, burrs, barbs or other features to engage the dura mater of IPS walls **114** and **117** (or the walls of CS lumen **131**), which further secures the anchor in IPS **102** or CS **104**.

The delivery catheter **304**, with or without a delivery guide wire, facilitates navigation and delivery of the anchor **700** within the patient's vasculature through the junction **118** and into the IPS **102** and/or CS **104**. The compressible nature of the anchor **700** allows the clinician to deploy the anchor **700** from the delivery catheter **304** within the IPS **102** (or CS **104**), re-sheath the anchor **700** into the delivery catheter **304** (when needed), and redeploy the anchor **700** within the applicable sinus lumen (e.g. IPS **102** and/or CS **104**) until the clinician is satisfied with the deployment location and orientation of the anchor **700** and/or elongate guide member **780** in the patient.

As shown in FIG. **7**A, the anchor **700** is deployed in the IPS **102**. The anchor **700** is disposed in the IPS **102** distal to a target penetration site in IPS wall **114**. The elongate guide member **780** coupled to the anchor **700** extends from the IPS **102** through the curved portion of IPS **102** into the junction **118**. The elongate guide member **780** further extends into the jugular vein **106**, and can extend further through venous vasculature and out of the patient's body at the peripheral access site (e.g., femoral vein). The delivery catheter **304** used to deploy the anchor **700** may be withdrawn from the patient to allow for other delivery system components to access the IPS **102** after deployment of the anchor. Alternatively, the delivery catheter **304** used to deploy the anchor **700** may allow further deployment of other components (e.g., piercing or penetrating elements, shunts, or their like) into the IPS **102** without needing withdrawal of the delivery catheter **304** for other delivery systems. As previously disclosed, the anchor **700** can be deployed in a more distal location, such as CS **104**.

The shunt **200** capitalizes on a favorable pressure gradient between the subarachnoid space **116** (e.g., CP angle cistern **138**) and venous system (e.g., IPS **102**, jugular vein **106**, and/or a jugular bulb **108**) to drive CSF through the shunt **200** (i.e., inner lumen). In patients without hydrocephalus, the normal differential pressure between the intracranial pressure of the subarachnoid space **116** and blood pressure of the venous system is about 5 to 12 cm H_2O; this differential pressure between the subarachnoid space and venous system can be significantly higher in hydrocephalic patients. Once deployed and implanted, the shunt **200** facilitates one-way flow of CSF from the subarachnoid space **116** into the jugular the bulb **108** and/or jugular vein **106** where CSF is carried away by venous circulation, similar to the way that normally functioning arachnoid granulations drain CSF into the venous system. The shunt **200** prevents backflow of venous blood into subarachnoid space **116** via one or more one-way valves or any other flow regulating mechanisms. The shunt **200** allows for a more physiologic drainage of CSF by directing CSF into the cerebral venous system, a process that occurs naturally in people without hydrocephalus. In this manner, the pressure created by the excess CSF in the subarachnoid space **116** is relieved, and patient symptoms due to hydrocephalus can thereby be ameliorated or even eliminated. The shunt **200** of FIGS. **7**E-F includes a valve **209** as the flow regulating mechanism configured to regulate fluid flow through the shunt **200** into the venous system.

In embodiments of the inventions, a target flow rate of CSF (e.g., in a range of about 5 ml per hour to about 15 ml per hour) through the shunt **200** at a normal differential pressure is defined as being in a range between about 5 cm H_2O to about 12 cm H_2O between the subarachnoid space **116** and venous system (e.g., jugular vein **106** and/or a jugular bulb **108**).

In some embodiments, a target flow rate of CSF through the shunt **200** and/or valve **209** is approximately 10 ml per hour at a range of differential pressure between the subarachnoid space **116** and venous system ("ΔP") between 3 to 5 mmHg. A maximum flow rate of CSF through the shunt **200** and/or valve **209** can exceed 20 ml per hour and typically occurs immediately after shunt implantation in a patient with elevated ICP (e.g., ICP greater than 20 cm H_2O). The valve **209**, as the flow regulating mechanism of the shunt **200**, comprises a normal operating range (CSF flow direction) of 0.5 to 8 mmHg ΔP, having a valve opening pressure (CSF flow direction) of approximately 0.5 mmHg ΔP, and a reverse opening pressure (backflow prevention) of at least −115 mmHg ΔP. Additionally, the valve **209** may comprise an allowable CSF leakage (flow direction) of less or equal to 0.5 ml per hour, and/or an allowable blood backflow (reverse direction) of less or equal to 0.25 ml per hour.

A positive pressure gradient between the intracranial pressure (ICP) of the subarachnoid space and the blood pressure of the venous system may contribute to the natural absorption of CSF through arachnoid granulations. ICP greater than 20 cm H20 is considered pathological of hydrocephalus, although ICP in some forms of the disease can be lower than 20 cm H20. Venous blood pressure in the intracranial sinuses and jugular bulb and vein can range from about 4 cm H20 to about 11 cm H20 in non-hydrocephalic patients, and can be slightly elevated in diseased patients. While posture changes in patients, e.g., from supine to upright, affect ICP and venous pressures, the positive pressure gradient between ICP and venous pressure remains relatively constant. Momentary increases in venous pressure greater than ICP, however, can temporarily disturb this gradient, for example, during episodes of coughing, straining, or valsalva.

The shunt **200** and/or the valve **209** are configured to handle expected acute and chronic differential pressures between the subarachnoid space **116** and venous system ("ΔP") when implanted in a patient. A maximum, acute negative ΔP occurs, for example, between a maximum venous pressure (VP) and a minimum intracranial pressure (ICP), such as, if the patient coughs while moving from a supine to upright position. Embodiments of the valve **209** are configured to seal, shut and/or close under the negative ΔP conditions (i.e., when venous pressure exceeds intracranial pressure), preventing venous blood from flowing back through the shunt **200** into the subarachnoid space **116**. A maximum, acute positive ΔP occurs, for example, between a maximum ICP and a minimum VP, such as the acute positive ΔP caused by coughing when the patient transitions from an upright to supine position. Additionally, the shunt **200** and/or the valve **209** are configured to handle chronic elevated, positive ΔP conditions (e.g., approximately two or more minutes of elevated positive ΔP, such as between maximum hydrocephalus ICP and normal VP [e.g., hydrocephalus with low expected VP]); and to handle chronic, elevated negative ΔP conditions (e.g., approximately two or more minutes of negative ΔP, such as between minimum ICP and maximum VP [e.g., supine→upright posture change with minimal VP adjustment]).

In some embodiments, a delivery catheter **3304** can include one or more features that allow for accurate guidance, navigation and/or control of the deployment of the penetrating element and/or the shunt, particularly when passing through the junction **118** into the IPS **102**. FIGS. **8**A-B illustrate perspective and cross-sectional views of the delivery catheter **3304**, according to one embodiment of the disclosed inventions. The delivery catheter **3304** comprises a recess **3313** formed in the outer surface **3310** of the catheter. The recess **3313** is configured to slidably engage the elongate guide member **780** of the anchor **700**, so that the delivery catheter **3304** rides on the elongate guide member **780** of the previously deployed anchor **700** (e.g., "side car" configuration), allowing the catheter **3304** to be guided in a desired orientation and location within the target site in the IPS **102**, as shown in FIG. **7**B. The elongate guide member **780** is dimensioned and configured to engage the recess **3313** in the delivery catheter **3304**. The elongate guide member **780** is further configured to guide the delivery catheter **3304** into the target penetration site, as shown in FIGS. **7**B and **7**D. The embodiment shown in FIGS. **8**A-B is an exemplary control feature that can be implemented in connection with the catheter **3304**. In some embodiments, the catheter **3304** and anchor **700** can include a plurality of such features (e.g., a plurality of elongate guide members that engage with a plurality of recesses).

As shown in FIG. **7**B, the delivery catheter **3304** has been advanced over, in or on the elongate guide member **780** of the previously deployed anchor **700**. Alternatively to the recess **3313** disclosed above, the delivery catheter **3304** can have a dedicated lumen **3315** extending between the delivery catheter proximal and distal portions configured to accommodate the elongate guide member **780** of the anchor **700**. Alternatively, the delivery catheter **3304** can include a broken or incomplete lumen extending between the proximal and distal portions of the catheter that captures the elongate guide member **780** against IPS wall **117** and allows the catheter to travel over the elongate guide member **780**. At least one other lumen **3305** of delivery catheter **3304** extends between the proximal and distal portions of the catheter **3304** (FIGS. **8**A-B, and FIG. **9**), which allows for navigation and delivery of the penetrating elements (e.g., surgical tool, needles, RF stylets, or the like) and shunt devices, with or without penetrating distal tip disclosed herein, and in the related application previously incorporated by reference herewith. The distal portion **3344** of the delivery catheter **3304** intersects the IPS wall **114** at an angle of approximately 75° (or any other suitable angle) at the target penetration site, as shown in FIG. **7**B.

FIGS. **10**A-K depict additional embodiments of a dual lumen delivery catheter **3304**. As shown in FIGS. **10**A-E, a distal portion **3344** of the delivery catheter includes a penetrating element **3350**. Each catheter of FIG. **10** includes a first lumen **3315** extending between the ends of the catheter, which is configured to receive the elongate guide member **780** and, optionally, conforms to the profile of the elongate guide member. A second lumen **3305** of the foregoing catheter embodiments extends between the ends of the catheter, which allows for navigation and delivery of the penetrating elements (e.g., surgical tool, needles, RF stylets, or their like) and shunt devices with or without penetrating distal tip disclosed herein, and in the related application previously incorporated by reference herewith. Further, one or both lumens of delivery catheter **3304** shown in FIGS. **10**A-K can include a liner and/or can be coated with a hydrophilic agent to increase the lubricity of such lumens with respect to other delivery assembly components as described in the related application previously incorporated by reference herewith. FIGS. **10**B, **10**D, and **10**E-J show elongate guide member **780** disposed within first lumen **3315**, and FIGS. **10**B, **10**E-J show the shunt **200** with a hollow inner lumen **207** disposed within second lumen **3305** for the exemplary delivery catheter **3304** embodiments. It should be appreciated that the dimensions depicted in **10**A-K are exemplary dimensions of the delivery catheter **3304**, first lumen **3315**, second lumen **3305**, penetrating element **3350**, shunt **200**, and shunt lumen **207**, which are not intended to limit the scope of embodiments disclosed herein. For example, embodiments of delivery catheter **3304** can have a second lumen **3305** with an inner diameter in a range of about 0.012" (0.3048 mm) to 0.040" (1.016 mm) or more.

The anchor **700** and the elongate guide member **780** can be optimized to orient the penetrating element or shunt advancing via the catheter **3304** over the elongate guide member **780** towards a target penetration site on the IPS wall **114** along the curved portion of IPS **102**. For example, the elongate guide member **780** coupled to the anchor **700** at a location along the top edge of anchor **700**, is configured to orient a distal portion **782** of the elongate guide member **780** proximate or adjacent to the IPS wall **114**, as shown in FIGS. **7**A-B. Alternatively, the anchor **700** and the elongate guide member **780** can be configured such that the elongate guide member **780** orients (e.g., "hugs") nearest the IPS wall **117** through the curved portion of IPS **102**, as shown in FIGS. **7**C-D, when the anchor **700** is deployed distally to a target penetration site along the IPS wall **114**.

Additionally, the deployment location of the anchor **700** in the sinus lumen can vary the path of the elongate guide member **780** through the curved portion of IPS **102**, regardless of how the elongate guide member **780** is oriented with respect to the top, midline, or bottom portions of the anchor **700**. For example, deploying the anchor **700** more distally than the deployment location shown in FIGS. **7**A-B will orient the elongate guide member **780** more proximate to the IPS wall **117** than IPS wall **114**.

Additionally, embodiments of the delivery catheter **3304** (or a shunt if delivered over the elongate guide member **780** without a delivery catheter) can be optimized to orient a penetrating element and/or shunt advancing through or over the elongate guide member **780** towards a target penetration site in the IPS wall **114** along the curved portion of IPS **102**. The distal portion **3344** of the delivery catheter **3304** can have multiple interface points to accommodate the elongate guide member **780**, as denoted by the "x" markings in FIG. **7**D. The interface point on the distal portion **3344** of delivery catheter **3304** for the elongate guide member **780** provides a penetration stop to limit the distance the penetrating element **3350** can travel through IPS wall **114** and into CP angle cistern **138** (e.g., the maximum penetration depth corresponds to the distance between the distal tip of penetrating element **3350** and the interface point on delivery catheter **3304** for receiving elongate guide member **780**). Introducing the elongate guide member **780** into or along the delivery catheter **3304** at a more proximal location on the catheter **3304** allows for more separation between the penetrating element **3350** and/or a distal open end **3341** of the delivery catheter **3304** and the elongate guide member **780**. The greater extent of separation between the penetrating element **3350** and elongate guide member **780** provides a relatively longer depth of penetration through IPS wall **114** and arachnoid layer **115** along the curved portion of IPS **102**. Conversely, a more distal entrance point or connection along the delivery catheter **3304** and the elongate guide member **780** decreases the separation between the elongate guide member **780** and the penetrating element **3350** and/or distal open end **3341** of delivery catheter **3304**. The lesser extent of separation between the penetrating element **3350** and elongate guide member **780** provides a relatively shorter depth of penetration through IPS wall **114** and arachnoid layer **115** along the curved portion of IPS **102**. A clinician can adjust the interface point between the elongate guide member **780** and delivery catheter **3304** to optimize the trajectory of a penetrating element from the delivery catheter **3304** and penetration depth at a target penetration site along the IPS **114**. The interface point between the elongate guide member **780** and delivery catheter **3304** can range from the distal end **3341** of delivery catheter **3304** (e.g., where the distal end of the delivery catheter includes a distal opening to a dedicated rail lumen) to an interface point about 10 cm proximal from the distal end of delivery catheter **3304**.

Once deployed, the anchor **700** and the elongate guide member **780** provide a stable, intra-sinus platform that creates an off-axis trajectory for the penetrating element during shunt implantation. The deployed anchor **700** and elongate guide member **780**, along with other aspects of the delivery system, afford clinicians controlled access to the greatest extent of CSF-filled space in the CP angle cistern **138** during shunt deployment. The elongate guide member **780** extending through the curved portion of IPS **102** advantageously orients the penetrating element **3350** (i.e., advancing via the guide member) toward IPS wall **114** into CP angle cistern **138**. As shown in FIG. 7D, the portion of delivery catheter **3304** distal of the interface point separates from the axis of the elongate guide member **780** as the delivery catheter advances over the guide member through the curved portion of the IPS; that is, the distal most portion of delivery catheter **3304** including penetrating element **3350** travel off-axis from elongate guide member **780** to puncture IPS wall **114** and access the CSF-filled CP angle cistern **138**. This orienting feature of the elongate guide member with respect to delivery catheter **3304** ensures that advancement of the penetrating element will: (a) intersect the IPS wall **114** at a target penetration site along the curved portion of IPS **102** at an angle of approximately 90° (i.e., oriented orthogonal to IPS wall **114**) to approximately 30° (although, other suitable angles may be provided), and (b) continue on a trajectory through the dura mater of the IPS wall **114** and through the arachnoid layer **115** to access at least 2-3 mm of unobstructed, CSF-filled space of CP angle cistern **138** as measured distally from the penetration point on the IPS wall **114**. Features of anchor **700** and the elongate guide member **780** disclosed herein allow clinicians to access and deploy a shunt in a relatively larger extent of free CSF-filled space in the cistern, often more than 3 mm to 5 mm of unobstructed CSF-filled space, compared to other endovascular shunt delivery techniques.

After the anchor **700** and the elongate guide member **780** have been deployed at a desired location in the sinus lumen and the penetrating element has been advanced over the elongate guide member **780** to a target penetration site along the IPS wall **114**, the clinician can proceed by creating anastomosis between the IPS **102** and the CP angle cistern **138**, followed by the shunt delivery and implantation steps of procedure. The clinician can penetrate the IPS wall **114** to access the CP angle cistern **138** with the penetrating element (e.g., penetrating element advanced via the catheter, on the shunt, or carried by the catheter distal end) by pulling the elongate guide member **780** in the proximal direction (or locking the elongate guide member **780** in place relative to other delivery system components) while advancing the penetrating element over the elongate guide member **780**, toward the IPS wall **114**. The retrograde force on the elongate guide member **780** during the penetration step further secures the guide member and anchor **700** in the sinus lumen, thereby stabilizing the elongate guide member **780** in the curved portion of the IPS **102** while it orients a penetrating element towards IPS wall **114** and off-axis from the trajectory of elongate guide member **780** in the curved portion of the IPS lumen. And by simultaneously advancing the penetrating element and/or shunt **200** (as previously disclosed) through the IPS wall **114** and arachnoid layer **115** until a distal anchoring mechanism **229** of the shunt **200** is deployed in the CP angle cistern **138** (i.e., without an exchange of delivery system components between the penetration and shunt deployment steps) eliminates the risk of bleeding from the sinus lumen into the subarachnoid space.

Radiopaque markings or coatings can be incorporated on the penetrating element **3350** (e.g., penetrating element advanced via the catheter, on the shunt, or carried by the distal end of the delivery catheter) and/or the delivery catheter to assist the clinician visualize the orientation of delivery system elements in the sinus lumen and the trajectory of such elements prior to or during the penetration step of the shunt implant procedure. For example, a semi-circle piece or half-band of radiopaque material can be coupled to or incorporated within the penetrating element **3350** and/or in the distal portion **3344** of the delivery catheter **3304**. Depending on the location of the marker in the penetrating element **3350** and/or distal portion **3344** of the delivery catheter **3304** (e.g., distal section or proximal section of the penetrating element to assist with the visualization of the respective section of the inner diameter or lumen), the clinician can confirm whether the penetrating element **3350** is properly oriented toward the IPS wall **114** and/or improperly oriented toward the IPS wall **117**.

After the distal anchoring mechanism **229** of the shunt **200** has been deployed in the CP angle cistern **138**, the delivery catheter **3304** can be withdrawn (i.e., pull in the proximal direction) from the curved portion of IPS **102**. The distally anchored shunt **200** emerges from the distal end opening **3341** of the delivery catheter **3304** as the catheter is withdrawn through the IPS **102** into the junction **118**; the distal anchoring mechanism of the shunt disposed within the CP angle cistern **138** retains, secures and/or anchors the shunt in its deployed location within the subarachnoid space **116** as the delivery catheter **3304** is withdrawn from the IPS **102**. Thereafter, the delivery catheter **3304** can be further withdrawn through the junction **118** to allow the proximal anchoring mechanism **227** of shunt **200** to be deployed in the jugular vein **106**, as shown in FIG. **7**E.

After the shunt **200** has been fully deployed and/or secured at the target site by the shunt **200** respective anchoring mechanisms **227**, **229**, the clinician can advance the delivery catheter **3304** and/or a micro catheter (e.g., catheter having an inner diameter of 0.027" or 0.021") over the elongate guide member **780** to re-sheath the anchor **700**, and then withdraw the catheter **3304** containing anchor **700** and elongate guide member **780** from the patient (e.g., via a femoral access point). Alternatively, the elongate guide member **780** can include an electrolytic detachment element **785** in or around the joint **744** with anchor **700** (FIGS. **3**C, **3**H) or at any other suitable portion of the elongate guide member **780** (e.g., FIG. **7**F), so as to detach the elongate guide member **780** from the anchor **700**. After detachment of the elongate guide member **780** from the anchor **700**, the elongate guide member **780** can be withdrawn from the patient while anchor **700** remains deployed in the IPS **102** or CS **104**. This configuration can be advantageous to avoid accidental pullout of an implanted shunt from CP angle cistern **138** while retrieving the anchor **700** from its distal deployment location by snagging the anchor **700** on a portion of the deployed shunt, as the anchor **700** is withdrawn through the IPS **102** and the junction **118**.

In further alternative embodiments, the electrolytic detachment element **785** can be proximately disposed from the joint **744** (e.g., at the elongate guide member **780** portion configured to be disposed around the junction **118**), as shown in FIGS. **7**E and **7**F. The anchor **700** and a portion of the elongate guide member **780** can be part of the implanted shunting system where a deployed shunt includes one or more connection points or interfaces with the elongate guide member **780**, allowing the deployed anchor **700** and portion of the elongate guide member **780** to further anchor the shunt at its deployed location. In such embodiments, the elongate guide member **780** can include the electrolytic detachment element **785** at a portion of the elongate guide member **780** configured to be disposed around the junction **118**. So that, a proximal portion **780'** (i.e., proximately to the electrolytic detachment element **785**) of the elongate guide member **780** is withdrawn from the patient after deployment of the shunt, while the distal portion of the elongate guide member **780** remains coupled to the anchor **700**. In this embodiment, the anchor **700** may further provide a scaffold support for the deployed shunt **200**, as shown in FIG. **7**F.

The anchor **700** and the elongate guide member **780** system can have the following advantages over other endovascular shunt delivery systems and techniques:

Separate anchor **700** and shunt **200** deployment steps preserve critical working and deployment space in the IPS **102** and/or CS **104** around the target penetration site to accommodate delivery system components such as delivery catheter **3304** and shunt **200** compared to a delivery system configured for a single anchor and shunt **200** deployment step comprising multiple, concentric elements (e.g., a delivery catheter, delivery system anchor and/or guide wire, a shunt, and a penetrating element).

The anchor **700** and the elongate guide member **780** system provides a stable platform to secure delivery system components during (a) penetration through the dura mater IPS wall **114** and arachnoid layer **115** into CP angle cistern **138**, and (b) deployment of the shunt distal anchoring mechanism **229** in the cistern compared to a conventional delivery catheter and guide wire system.

The anchor **700** and the elongate guide member **780** system resists "kickout" of delivery system components (e.g., delivery catheter **3304**) from the IPS **102** and/or CS **104** into the jugular vein **106** resulting from tortuous anatomy during critical procedure steps such as penetrating dura mater IPS wall **114** and arachnoid layer **115** and deploying the shunt and its distal anchoring mechanism **229**.

In some embodiments of anchor **700**, for example when the anchor is left behind in the sinus lumen (IPS **102** or CS **104**) to secure that the implanted shunt **200**, the anchor can be configured for hydraulic expansion using stainless steel or cobalt chromium materials, thereby simplifying system design and reducing product manufacturing costs.

The elongate guide member **780** extending proximally from a deployed anchor **700** along the IPS wall **117** eliminates or decreases the risk that an uncovered or unprotected penetrating element inadvertently snags a portion of the IPS wall **114** as the penetrating element is delivery to the target penetration site.

FIGS. **12**A-F illustrate an alternative delivery catheter **1304** for delivering a shunt into a target site of a patient, constructed in accordance with embodiments of the disclosed inventions. For ease in illustration, the features, functions, and configurations of the delivery catheter **1304** that are the same as in the delivery catheters **304** and **3304** of the present disclosure and the delivery catheters **304**, **304'** in the related application previously incorporated by reference herewith, are given the same reference numerals. The delivery catheter **1304** comprises an elongated configuration having a proximal portion **1342**, a distal portion **1344** and a lumen **1341** extending therebetween. The delivery catheter **1304** is dimensioned to reach remote locations of the vasculature and is configured to deliver the shunt percutaneously to the target site (e.g., IPS, CS, CP angle cistern, or the like). The delivery catheter **1304** comprises variable stiffness sections (e.g., varying ratio of material, including selective reinforcement, varying the properties or distribution of the materials used and/or varying the durometer or thickness of the materials during the process of manufacturing) suitable to provide sufficient "pushability" (e.g., exhibits sufficient column strength to enable delivery to target locations such as IPS **102** or CS **104**; in embodiments comprising a tissue penetrating element **1350**, provides sufficient column strength to transmit about 0.1 N to 2.0 N force or more for the penetrating or piercing element to penetrate dura of IPS wall **114** and arachnoid layer **115**) and "torqueability" (e.g., in the vasculature exhibits a torque response of about 1:1 such that a single clockwise turn of the catheter at the patient's groin or proximal portion results in approximately single clockwise turn of the distal portion of the catheter at a target location such as IPS **102** or CS **104**) to allow the catheter **1304** to be inserted, advanced and/or rotated in the vasculature to position the distal portion **1344** of the catheter at the target site within the IPS **102** or CS **104**. Further, the distal portion **1344** has sufficient flexibility so that it can track and maneuver into the target site, particularly in tortuous anatomy.

Known components, such as embedded coils or braids, are often used to provide selective reinforcement to delivery catheters. Delivery catheters including embedded coils can provide suitable flexibility, however, the embedded coils usually fail to provide the necessary column strength for the catheter, particularly at the distal portion of micro-catheters. Delivery catheters including embedded braids can provide with suitable column strength, while sacrificing flexibility, particularly if the embedded braids are disposed at the distal portion of the catheter.

In the embodiments of FIGS. **12**A-C, the delivery catheter **1304** comprises an reinforcing member **1345** configured to reinforce the catheter **1304** while providing a suitable balance between column strength and flexibility (e.g., "pushability" and "torqueability"). The reinforcing member **1345** is composed of suitable biocompatible and elastomeric materials such as, stainless steel, Nitinol® or the like. In some embodiments, the reinforcing member **1345** comprises a stainless steel or Nitinol hypotube providing suitable column strength, the hypotube further comprises selective cuts **1330**, which provides suitable flexibility.

The reinforcing member **1345** may extend along a substantial length of the catheter **1304** (e.g., the reinforcing member **1345** extends from the proximal portion **1342** to the distal portion **1344** of the catheter **1304**). In the embodiment of FIG. **12**A, length L_{10}, measured along a central axis **1349** of the reinforcing member **1345** is approximately 59" (150 cm). Alternatively, the reinforcing member **1345** can extend along a section of the catheter **1304** (e.g., the reinforcing member **1345** extends along the distal portion **1344** without extending to the proximal portion **1342** of the catheter **1304**). For example, L_{10} can range between 1.9" (5 cm) to 6" (15.2 cm), or any other suitable length.

Further, in the embodiment of FIGS. **12**A-C, the inner diameter (ID) of the reinforcing member **1345** (e.g., lumen **1341**) measured in a direction orthogonal to axis **1349** can range between 0.0205" (0.5207 mm) to 0.024" (0.6096 mm), and the outer diameter (OD) of the reinforcing member **1345** measured in the same direction (i.e., orthogonal to axis **1349**) can range between 0.026" (0.6604 mm) to 0.03" (0.762 mm). It should be appreciated that the ID, OD and/or the L_{10} and any other length, width, or thickness of the reinforcing member **1345** of the delivery catheter **1304** may have any suitable dimension for delivering the shunt in the target site (e.g., IPS, CP angle cistern, or the like). Exemplary dimensions (in inches) and properties of the reinforcing member **1345** are shown in FIG. **12**G, which are not intended to limit the embodiment of FIGS. **12**A-C.

In the embodiments of FIGS. **12**A and **12**C, the reinforcing member **1345** comprises one or more cuts **1330** (e.g., kerfs, slots, key-ways, recesses, or the like) selectively disposed at the proximal portion **1342** and the distal portion **1344** of the reinforcing member **1345**. Additionally, the one or more cuts **1330** can be disposed in sections of the reinforcing member **1345** along L_{10}, as shown by the exemplary spiral cut pattern of kerf, pitch, cuts per rotation and cut balance depicted in sections of FIG. **12**A. Alternatively, the cuts **1330** can be continuously disposed substantially along L_{10} (not shown), and the continuously disposed cuts **1330** can have variable spiral cut patterns of kerf, pitch, cuts per rotation and cut balance along L_{10} or combinations thereof.

The cuts **1330** of the reinforcing member **1345** can have a variety of suitable patterns, and can be manufactured by laser cutting the reinforcing member **1345** of the delivery catheter **1304**. Alternatively, the cuts **1330** and their patterns can be manufactured by etching or other suitable techniques. FIGS. **12**E-F depict an exemplary cut pattern of the reinforcing member **1345** of FIGS. **12**A-C. In these embodiments, the laser cutting of the reinforcing member **1345** creates between 1.5 to 2.5 cuts **1330** per rotation of the reinforcing member **1345**, having a cut balance of between 100° to 202° of rotation with laser on, and then 34° to 38° of rotation with laser off.

As shown in FIG. **12**A, the cuts **1330** of the reinforcing member **1345** that are disposed at the proximal portion **1342** comprise a larger pitch (e.g., 0.015) than the pitch (e.g., 0.006) of the cuts **1330** disposed at the distal portion **1344** of the reinforcing member **1345**. The smaller the pitch of the cuts **1330** (i.e., smaller separation between cuts) provides for an increase in flexibility of the reinforcing member **1345**, such as at the distal portion **1344** of the delivery catheter **1304**. The transition between the larger pitch to the smaller pitch cuts **1330** can be subtle, providing for a progressively more flexible delivery catheter towards the distal portion. By way of non-limiting examples, the spiral cut pattern to create the cuts **1330** disposed at the proximal portion **1342** of the reinforcing member **1345** comprise a kerf of 0.001, a pitch of 0.015, creating 2.5 cuts per rotation, having a cut balance of 100° of rotation with laser on, and then 34° rotation with laser off. The spiral cut pattern applied to create the cuts **1330** disposed between the proximal portion **1342** and the distal portion **1344** of the reinforcing member **1345** comprises a kerf of 0.001, a pitch transition from 0.006 to 0.015, creating 1.5 cuts per rotation, having a cut balance of 202° of rotation with laser on, and then 38° rotation with laser off. The spiral cut pattern applied to create the cuts **1330** disposed at the distal portion **1344** of the reinforcing member **1345** comprises a kerf of 0.001, a pitch of 0.004, creating 1.5 cuts per rotation, having a cut balance of 202° of rotation with laser on, and then 38° rotation with laser off. The cuts **1330** may have a width that ranges between 0.0005" (0.0127 mm) to 0.002" (0.0508 mm), or any other suitable width. It should be appreciated that the width, length and depth of the cuts **1330** and patterns of the cuts **1330** in the reinforcing member **1345** of the delivery catheter **1304**, can comprise any suitable dimensions. By way of non-limiting example, the pattern of cuts **1330** can transition to a larger pitch (e.g., greater than 0.004) in the distal portion **1344** of reinforcing member **1345** to increase column strength and provide support to a delivery catheter during the penetration step of the shunt implant procedure.

Additionally, the reinforcing member **1345** comprises an inner liner **1360** and an outer jacket **1365**, as better seen in FIG. **12**C. The inner liner **1360** and outer jacket **1365** are composed of suitable implantable polymeric materials, such as polytetrafluoroethylene "PTFE", polyethyleneterephthalate "PET", High Density Polyethylene "HDPE", expanded polytetrafluoroethylene "ePTFE", urethane, silicone, or the like. The inner liner **1360** and outer jacket **1365** are configured to cover—completely or partially—the cuts **1330** of the reinforcing member **1345**, from within lumen **1341** and over the elongated member outer surface **1370**, respectively. In such configuration, the reinforcing member **1345** becomes an impermeable tubular element having the cuts **1330** covered by the respective inner liner **1360** and outer jacket **1365**, while maintaining the flexibility provided by the selective cuts **1330** and column strength afforded, in part, by the reinforcing member **1345**.

The inner liner **1360** provides a smooth inner surface in the lumen **1341** of the reinforcing member **1345** that facilities translation and delivery of the shunt (or other delivery systems or devices delivered through the lumen). Further, the inner liner **1360** can be configured to line the interior reinforcing member **1345** using an extrusion process. Alternatively, the liner material can be deposited (e.g., using a dispersion technique) on a mandrel (e.g., nickel coated copper); thereafter, the liner-coated mandrel can be placed within the reinforcing member **1345** for application of outer jacket **1365** and adhering the inner liner **1360** to the reinforcing member **1345**, after which the mandrel can be withdrawn from the reinforcing member **1345** leaving inner liner **1360** in place within the lumen **1341** of the reinforcing member **1345**.

The outer jacket **1365** provides a smooth outer surface to the reinforcing member **1345**, which facilitates the navigation of the delivery catheter **1304** through tortuous vasculature. As noted above, the outer jacket **1365** can comprise one or more implant-grade polymers including, but not limited to, polyurethane or silicone-polyurethane blends. In some embodiments, a gas or liquid dispersion of polymer is applied to the reinforcing member **1345** and inner liner **1360**, which forms the outer jacket **1365** and bonds the inner liner **1360**, the reinforcing member **1345**, and outer jacket **1365** together in an integrated configuration of the delivery catheter **1304**.

The outer jacket **214** can substantially cover the entire outer surface of the reinforcing member **1345**; however, in some embodiments, the outer jacket can be placed selectively along sections of reinforcing member **1345** to adhere the inner liner **1360** to the reinforcing member **1345**. By way of non-limiting example, a liquid dispersion of polymer or an epoxy-based adhesive can be placed at discrete locations along L_{10}. Alternatively, the outer surface of inner liner **1360** can be coated with polymer or adhesive, and then placed within reinforcing member **1345**; the polymer or adhesive can seep into the cuts **1330**, completely or partially filling some or all of the cuts **1330** along L_{10}.

In the embodiment of FIG. **12**C, the inner liner **1360** can have a thickness of 0.0005" (0.0127 mm); though the thickness of inner liner **1360** can range from 0.0005" (0.0127 mm) to 0.0015" (0.0381 mm) in other embodiments. In the embodiment of FIG. **12**C, the outer jacket **1365** can have a thickness of 0.001" (0.0254 mm); though the thickness of outer jacket **1365** can range from 0.0001" (0.00254 mm) to 0.001" (0.0254 mm) in other embodiments. It should be appreciated that the inner liner **1360**, and the outer jacket **1365** of the reinforcing member **1345** may comprise any suitable dimensions.

Referring back to FIG. **12**A, the reinforcing member **1345** further comprises a penetrating element **1350** (e.g., sharp, tapered, cannula-like end, bevel, pencil, or Quincke tip needle, or the like) extending or disposed at the distal portion **1344** of the elongated member, as also depicted in FIG. **12**D. The penetrating element **1350** is configured to penetrate the dura mater of the IPS wall **114** and the arachnoid layer **115** creating an anastomosis between the IPS **102** and the CSF-filled CP angle cistern **138** for deployment of the shunt, as previously disclosed herein, and in the related application previously incorporated by reference herewith. The cuts **1330** proximately disposed to the penetrating element **1350** are configured to provide suitable flexibility to the distal portion **1344** of the delivery catheter **1304**, allowing the distal portion **1344** to bend, curve and/or orient the penetrating element **1350** towards the IPS wall **114**, while maintaining suitable column strength to support the penetrating element **1350** at the distal portion **1344** as it penetrates through the IPS wall **114** and arachnoid layer **115**. The penetrating element **1350** extending from, integrated with and/or incorporated to the distal portion **1344** of the reinforcing member **1345** allows for a secure withdrawal of the penetrating element **1350** when the delivery catheter **1304** is withdrawn from the patient.

FIG. **13** illustrates an elongated pusher **3710**, constructed in accordance with embodiments of the disclosed inventions. The elongated pusher **3710** comprises a support tubular member **3711**, having a proximal portion **3712**, a middle portion **3713** and a distal portion **3714**, and a lumen **3724** extending therebetween. The proximal portion **3712** of the support tubular member **3711** is coupled to a handle **3722**, which will be described in further detail below. The pusher **3710** provides telescoping support to a guidewire or other interventional devices as a clinician translates such guidewire or device through a catheter to a target site.

The elongated pusher **3710** is configured to translate (e.g., advance, push) interventional access/treatment devices (e.g., stent anchor **700**, guide member **780**, guidewires, thrombectomy devices, or the like) into the IPS **102** or any other target site, through a catheter (e.g., delivery catheter **304/3304**, or the like) disposed in a patient's vasculature. The pusher **3710** is further configured to receive the elongated guide member **780**, and the handle **3722** is configured to assist the clinician hold a portion of the guidewire or interventional devices extending proximally through the handle lumen **3724** thereby advancing the guidewire and/or interventional devices through a catheter.

The length of the support tubular member **3711** can range from about 1" (2.54 cm) to about 60" (152.4 cm) or larger. The support tubular member **3711** comprises an inner wall defining the lumen **3724**, the inner wall can include an annular, circular or any other suitable shape or dimension suitable for advancing guidewires and/or interventional devices therebetween. The inner diameter of the support tubular member **3711** can range from about 0.010" (0.254 mm) to about 0.024" (0.6096 mm). In some embodiments, the inner diameter of the of the support tubular member **3711** is larger than 0.024" (0.6096 mm), such that the pusher **3710** is configured to receive and translate larger guidewires and/or other interventional devices (e.g., 2-24 Fr). The outer diameter of the support tubular member **3711** is configured to be received into the proximal hub **3377** of a catheter or hemostasis valve through which guidewires and/or other interventional devices will be advanced into the patient's target site. The support tubular member **3711** can have a thin-walled configuration, comprising a wall thickness that ranges from about 0.001" (0.0254 mm) to about 0.005" (0.127 mm), which allows the support tubular member **3711** to fit within the catheter hub while maintaining maximum clearance within the tubular member lumen **3724** for receiving guidewires and/or interventional devices. By way of non-limiting example, an embodiment of the pusher **3710** configured for translating embodiments of anchor **700** and guide member **780** through an 0.027" micro catheter into a distal portion of the IPS can have a support tubular member **3711** that is 6" to 8" (15.25 to 20.32 cm) long, with an outer diameter of 0.025" (0.635 mm) and inner diameter of 0.020" (0.508 mm). Alternative embodiments can be configured for translating larger or smaller interventional devices through larger or smaller catheters; for example, embodiments of the pusher can be configured for translating neuro-interventional devices such as 0.010", 0.014", or 0.018" guidewires through 0.014", 0.018", or 0.021" micro catheters.

The support tubular member **3711** of the elongated pusher **3710** can be composed of metal (e.g., stainless steel, titanium, Nitinol) or plastic (e.g., polyamide, polyimide, PTFE, PEEK, polyester), or combinations thereof. The support tubular member **3711** can have a multi-layered construction, for example, stainless steel exterior with an HDPE inner layer. In embodiments of the support tubular member **3711** composed by metal, the tubular member **3711** can include progressive spiral cut or articulated construction, where cut pattern or articulations are configured to create stiffness that transitions along the length of the support tubular member **3711** (e.g., stiffness transitions over its length and becomes stiffer nearer to the handle **3722**. In such embodiments, the distal portion **3714** of the support tubular member **3711** is more flexible than the proximal portion **3712** (e.g., stiffer near the handle **3722**). Further, the inner wall of the support tubular member **3711** can include a PTFE liner or a lubricious coating such as PTFE, parylene, or other suitable hydrophilic coatings, configured to reduce friction or facilitate smooth translation of the guidewires and/or interventional devices through the tubular member lumen **3724**.

Referring back to the handle **3722** coupled to the proximal portion **3712** of the support tubular member **3711**, the handle **3722** comprises an outer surface **3725**, and a lumen **3726** in fluid communication with the lumen **3724** of the support tubular member **3711** of the pusher **3710**. The handle lumen **3726** is configured for receiving a proximal end **3712'** of the proximal portion **3712** of the support tubular member **3711**. The handle **3722** can be coupled to the proximal end **3712'** of the tubular member **3711** by an adhesive (e.g., an ultraviolet light-cured adhesive, cyanoacrylate, or epoxy), using a press-fit connection, or any other suitable techniques. In alternate embodiments, the proximal end **3712'** of the tubular member **3711** can be radially flared (e.g., outwardly flared, flared out, funnel-like configuration, or the like) with the handle **3722** molded around the flared proximal end **3712'** of the tubular member **3711**. The handle **3722** can be composed of polyethylene, HDPE, PTFE, PEEK, ABS, polycarbonate, ABS-polycarbonate, thermoplastic polyamide, or polyoxymethylene, or the like. In alternative embodiments of the pusher **3710**, the handle can comprise PEEK, polyvinylidene difluoride, or other thermoplastic polymers or materials suitable for autoclaving treatments that can be used with a metal tubular member **3711**.

The handle **3722** further comprises a lumen opening **3726'** configured for receiving the guidewire and/or interventional devices for advancement into a target site in a patient through the support tubular member lumen **3724**. In some embodiments, the handle **3722** can range in diameter (at its widest portion) from about 0.75" to 1.5 "(0.75 mm to 38.1 mm) or more, and have a length of about 0.5" to 1.5" (12.7 mm to 38.1 mm) or more. The handle lumen **3726** defines an annular, circular or any other shaped space suitable for advancing the guidewire and/or interventional devices therebetween. The handle **3722** can comprise an ergonomic configuration, as shown in FIG. **13**. The ergonomic configuration of the handle **3722** is suitable for providing a resting portion (i.e., surface **3725**) for the clinician's fingers, typically sized for the clinician's thumb or finger, while using the pusher **3710**. The resting surface **3725** is configured to be contoured for resting a human thumb or finger, such that the clinician can use the surface **3725** to hold, pinch, press or maintain a portion of the guidewire and/or the interventional devices extending out from the handle **3722** while using the pusher **3710**, with one hand only. By pinching the guidewire and/or interventional device against the resting surface **3725** of the handle **3722**, the clinician can advance the pusher **3710**, the guidewire or the interventional devices into the catheter. Then, the clinician can release the pinch and withdraw the pusher **3710** over the guidewire. The clinician may perform a sequence of pinching the guidewire, advancing the pusher and pinched guidewire, releasing the pinch and withdrawing the pusher over the guidewire (as shown in FIGS. **14**C-E), which sequence can be repeated until the guidewire and/or the interventional devices translates through the catheter and reach their target site. The handle **3722** may include other contour shapes or configurations (e.g., scallop, ramp, slopes or the like) that allow the clinician to hold, pinch, press or maintain the guidewire and/or the interventional devices against the surface **3725** of the handle **3722**. The surface **3725** can include a traction pad (e.g., a thin strip of silicone, swallow ribs or the like) configured to increase the friction coefficient between the handle and the clinician, to assist with the holding of the guidewire and/or the interventional devices against the handle **3722**. The traction pad may comprise a single silicone pad disposed on the surface **3725** of the handle **3722** or a silicone tab that folds over and sandwiches the guidewire and/or interventional devices pinched against the surface **3725** of the handle **3722**.

The handle **3722** can further comprise features that facilitate use of the pusher **3710**. In the embodiment of FIG. **13**, the handle **3722** comprises a neck **3737** (e.g., annular indentation, or the like) configured to be held or gripped by the clinician's fingers during use of the pusher **3710**, as shown in FIGS. **14**C-D. The handle **3722** further comprises a flange **3738** (e.g., annular outward rim, protruding collar, or the like) distally disposed from the neck **3737** of handle **3722**. The neck **3737**, either alone or in combination with the flange **3738**, is configured to assist the clinician's hold of the pusher **3710** and to control the push and pull motions of the pusher **3710** relative to the guidewire, interventional devices and/or catheter, while maintaining the position of the pusher **3710** at a desired location. Additionally, the handle **3722** can include a scalloped or tapered lead in to lumen opening **3726'** for additional support for guidewire and/or interventional devices used with the pusher **3710**. In alternative embodiments, a portion of the handle **3722** can include a guidewire torque features (e.g., rotating collet to lock wire or device in place).

During advancement of the guidewire and/or interventional devices into a target site of a patient using the elongated pusher **3710** of FIG. **13**, the clinician introduces the guidewire and/or interventional devices through the lumen opening **3726'** of the handle **3722**. Then, the clinician distally translates the guidewire and/or interventional devices into the pusher **3710** (i.e., handle lumen **3726** and tubular member lumen **3724**) while maintaining the proximal portion of the guidewire or interventional devices extending out of the handle **3722**.

FIGS. **14**A-F illustrate a method of use an elongated pusher according with embodiments of the disclosed inventions. By way of non-limiting example, FIGS. **14**A-E illustrate the pusher **3710** of FIG. **13** to translate a guide member **780** through a catheter **3307** (e.g., micro catheter, introducer sheath or the like). In these embodiments, the catheter **3307** has been advanced into the vasculature (e.g., the IPS) from a femoral vein access point in the patient. It should be appreciated that the elongated pusher **3710** constructed according to embodiments of the disclosed inventions may be used in other interventional procedures including, but not limited to, stent retriever delivery, distal protection device delivery, foreign body retrieval, delivery loops and snares, pacemaker implantation, and any other suitable medical procedure.

FIG. **14**A depicts the guide member **780** being advanced into the distal opening **3714'** of the support tubular member **3711**. It should be appreciated that anchor **700** coupled to the guide member **780** has already been inserted and translated through the catheter hub **3377** into the proximal portion of the catheter **3307** (not shown). Alternatively, the pusher **3710** and guide member **780** can be introduced simultaneously into the catheter hub **3377**. As shown, the clinician feeds the guide member **780** through pusher **3710**, via the distal opening **3714'** of the support tubular member **3711**, through tubular member lumen **3724** and handle lumen **3726**, such that the guide member **780** emerges from the opening **3726'** of the handle **3722**. Alternatively, the clinician may feed the guide member **780** through pusher **3710**, via the opening **3726'** of the handle **3722**, through the handle lumen **3726**, into the tubular member lumen **3724**. Then, the clinician advances the pusher **3710** over guide member **780** until distal portion **3714** of support tubular member **3710** accesses the catheter hub **3377** of catheter **3307** (FIG. **14**B).

In instances in which the body lumen is a blood vessel, the elongate guide member **780** is normally advanced into the blood vessel through an introducer sheath **3307** having a proximal opening outside of the patient and a distal opening (not shown) within the blood vessel, in which case advancing the pusher tool **3710** may include advancing the distal portion **3714** of the tubular body **3711** into the proximal opening of the introducer sheath **3307**. The proximal opening of the introducer sheath is normally accessed via the proximal introducer hub **3377**, in which case the method may further include grasping to thereby stabilize the introducer hub **3377** while advancing the distal portion **3714** of the tubular body **3711** through the hub **3377**.

The clinician then holds, pinches, or presses the guide member **780** against the handle **3722**, as described above, and further advances the pusher **3710** and guide member **780** into catheter hub **3377** of catheter **3307**. (FIGS. **14**C-**14**D). By pinching the guide member **780** against the resting surface **3725** of the handle **3722**, the clinician can advance the pusher **3710** and guide member into the catheter **3307**. Then, the clinician can release the pinch and withdraw the pusher **3710** over the guide member **780**, preferably while maintaining the distal portion **3714** of the support tubular member **3711** within the catheter hub **3377**. The clinician may perform a sequence of pinching the guide member **780**, advancing the pusher **3710**, releasing the pinch and withdrawing the pusher **3710** over the guide member **780** (as shown in FIGS. **14**C-F), which sequence can be repeated until the guide member **780** translates through the catheter **3307**, with the support tubular member **3711** telescoping into the catheter hub **3377** and guide member **780** reaching the target site. The clinician releases the pinch of the guide member **780** against the handle **3722** and withdraws the pusher **3710** over the guide member **780** after the guide member reaches the target site.

FIGS. **15**A-K illustrate another exemplary shunt **2200** constructed and implanted according to embodiments of the disclosed inventions. A proximal portion **2204** of the shunt **2200** includes an anchoring mechanism **2227** (i.e., proximal anchor), and a valve **2209** (e.g., duck-bill, cross cut, elastic vales, molded silicone valves as disclosed herein, or other suitable one-way valves). A distal portion **2202** of the shunt **2200** includes an anchoring mechanism **2229**. The shunt **2200** further comprises an elongate body **2203** extending between the proximal **2204** and distal **2202** portions. The anchoring mechanisms **2227** and **2229** include a plurality of respective deformable elements **2227***a* and **2229***a* (e.g., arms) that are disposed radially outward in the deployed configuration of the shunt **2200** (FIG. **15**A). Anchoring mechanisms **2227** and **2229** may have a preformed expanded or deployed configuration, for example, when constructed from super-elastic materials such as Nitinol®. The deployed anchoring mechanism **2227** engages the jugular bulb **108**, the jugular vein **106**, the IPS wall **117**, and/or another portion of the IPS **102**, anchoring the proximal portion **2204** of the shunt **2200** within the jugular vein **106**, so that the valve **2209** is disposed within the jugular vein **106** or at least facing the blood flowing through the jugular vein (e.g., transversally disposed towards the vein), as shown, for example in FIGS. 7E-F. Alternatively, the anchoring mechanism **2227** may engage the IPS walls **114** and **117** at the junction **118** (not-shown). The deployed anchoring mechanism **2229** secures the distal portion **2202** of the shunt **2200** within the CP angle cistern **138**, so that CSF flows through the implanted shunt **2200** into the jugular vein **106** (e.g., FIGS. 7E-F).

The anchoring mechanism **2227** and **2229** are formed by series of cuts **2222** and **2222'** (e.g., kerfs, slots, key-ways, recesses, or the like) along the length of the respective proximal **2204** and distal **2202** portions of the shunt **2200** (FIGS. **15**C1-G), forming the deformable elements **2227***a* (FIGS. **15**A-E) and **2229***a* (FIGS. **15**A, **15**D-E, **15**G, **15**J). The cuts **2222** and **2222'** and their patterns are preferably manufactured by laser cutting, etching or other suitable techniques. FIGS. **15**D-F illustrate exemplary patterns and dimensions of the cuts **2222** in the proximal portion **2204** of the shunt **2200**, the cuts **2222** forming the deformable elements **2227***a* configured to a flared open (e.g., funnel, flower-petal, or the like) deployed configuration (FIGS. **15**A-B and **15**I). The deformable elements **2227***a* in the flared-open deployed configuration of the anchoring mechanism **2227**, as shown in detail in the perspective view of FIG. **15**B, combined with a malecot distal anchor **2229** configuration, provides a "flarecot" shunt configuration as shown in FIG. **15**A. Further, FIG. **15**I illustrates another perspective view of the flared anchoring mechanism **2227**. The deformable element **2227***a* may comprise hinge-like points **2227***b* (e.g., living hinge, joint, or the like) to assist with the deployment of the anchor **2227** into the flared configuration. Each of the deformable elements **2227***a* is coupled to one or more adjacent deformable element **2227***a* defining a plurality of closed cells **2227***g*, as shown in FIG. **15**I. The anchoring mechanism **2227** having the plurality of closed cells **2227***g* is configured to minimize disruption and allow passage of fluids (e.g., blood, CSF) through the anchor **2227** when anchoring the proximal portion **2204** of the shunt **2200** within the jugular vein **106**.

Referring back to the anchoring mechanism or proximal anchor **2227** of FIGS. **15**A-B and **15**I, the deformable elements **2227***a* may include one or more radiopaque markers **2227***c* (e.g., gold, or other suitable radiopaque materials) for imaging purposes during the delivery of the shunt **2200**. The markers **2227***c* assist with the deployment and/or placement of the anchoring mechanism **2227** at the target site within the patient. Further, suitable markers **2227***c* can be included (e.g., embedded, attached, coupled) or applied (e.g., coatings) in/on the deformable elements **2227***a*. The radiopaque marking scheme on the proximal anchoring mechanism **2227** depicted in FIGS. **15**A-B and **15**I allows the clinician to visualize deployment of the proximal anchoring mechanism about the jugular vein **106**, as the anchor transitions from a radially compressed to a flared, deployed configuration. In the embodiments of FIGS. **15**A-B and **15**I, each of deformable elements **2227***a* include a first end portion **2227***a'* and a second end portion **2227***a''*, wherein at least two deformable elements **2227***a* are coupled at their respective first end portions **2227***a'* having an interlocking element **2227***d* therein. The anchoring mechanism **2227** includes one or more interlocking elements **2227***d* having a respective marker **2227***c*. The interlocking elements **2227***d* of the anchoring mechanism **2227** are sized and dimensioned to detachably engage the shunt **2200** to the delivery system (e.g., pusher member or the like), described in FIG. **15C-1** in further detail. Each interlocking element **2227***d* includes a substantially round shape, as shown in FIGS. **15**A-B, **15**I, and **15**K, configured to arcuate in the delivery configuration to conform to the delivery system, as shown in FIGS. **15C-1**, **15C-2** and **15**L. The interlocking elements **2227***d* may include any other suitable shape, such as spherical, rectangular, or the like. Further, each interlocking element **2227***d* have a recess **2227***e* (e.g., hole, eyelet, cavity, or the like) configured for receiving a respective marker **2227***c*. As shown in FIGS. **15**A-B and **15**I, the markers **2227***c* are formed as rivets by pressing a respective marker **2227***c* into the corresponding recess **2227***e*. The markers **2227***c* may extend or protrude out of the interlocking elements **2227***d* (e.g., riveted), as shown in FIGS. **15**A-B and **15**I, or may be flushed with the interlocking elements **2227***d* (e.g., welded), or may be coupled to the interlocking elements **2227***d* with any other suitable techniques or combinations thereof.

The interlocking elements **2227***d* of the proximal anchor **2227** are shaped and dimensioned to detachably engage (i.e., engage and disengage) an interlocking element **3336** coupled to the distal portion **3314** of a pusher member **3310**, as shown in FIGS. **15**C-**1** and **15**C-**2**. The pusher member **3310** (e.g., hypotube, such as a stainless steel hypotube (FIGS. **15**C-**1** and **15**C-**2**) comprises a plurality cuts **3311** to increase flexibility, a radiopaque marker **3314** (FIGS. **15**C-**1** and **15**C-**2**) for imaging purposes, and a distal interlocking element **3336** (FIGS. **15**C-**1** and **15**C-**2**) configured to interlock with corresponding interlocking elements **2227***d* of the anchoring mechanism **2227**. FIGS. **15**C-**1** and **15**C-**2** illustrate the interface between the pusher member **3310** and anchoring mechanism **2227** of the shunt **2200**, having the interlocking elements **2227***d* of the proximal anchor **2227** engaged with the interlocking element **3336** of the pusher member **3310**. FIG. **15**C-**1** further depicts the valve **2209** disposed on the proximal portion **2204** of the shunt **2200** within the compressed anchoring mechanism **2227**. The pusher member **3310** is configured to deliver the shunt **2200** through a delivery catheter while avoiding contact, bumping or interfering with the valve **2209**. While the interlocked anchoring mechanism remains compressed within lumen **3305** of the delivery catheter **3304**, the clinician can advance and retract the shunt **2200** within the delivery catheter prior to shunt deployment via pusher member **3310** (e.g., advancing shunt slightly proximal of the penetrating element **3350** to provide additional column strength to the delivery catheter **3304** during the penetration step of the shunt implant procedure, or alternatingly advancing the delivery catheter **3304** and then shunt **2200** through lumen **3305** to maintain the flexibility of the delivery assembly while accessing and navigating through tortuous anatomy).

In the embodiment of FIGS. **15**A-J, the proximal anchor **2227** is composed of super-elastic materials (e.g., Nitinol®) having a preformed, flared configuration. When the proximal portion **2204** of the shunt **2200** is advanced out of the delivery catheter by translating the pusher member **3310** and/or withdrawing the delivery catheter, with or without holding pusher member **3310** member in place, the anchor interlocking elements **2227***d* disengage from the interlocking element **3336** of the pusher member **3310** by the anchor **2227** assuming the flared configuration, shown in FIGS. **15**A-B and **15**I. In some embodiments, the flared configuration of the proximal anchor **2227** and/or disengaging of the anchor interlocking elements **2227***d* from the interlocking element **3336** of the pusher member **3310** may be actuated and controlled by the clinician.

Referring back to the anchoring mechanism or distal anchor **2229** of the shunt **2200**, FIG. **15**G illustrates exemplary patterns and dimensions of the cuts **2222'** in the distal portion **2202** of the shunt **2200** (FIGS. **15**A, **15**D-E, and **15**G). The cuts **2222'** are parallel and radially spaced to form the deformable elements **2227***a* configured to extend radially outward when deployed assuming a malecot configuration (FIGS. **15**A and **15**J). Each of the deformable elements **2229***a* has a respective hinge-like point **2229***b* (e.g., living hinge, joint, or the like) configured to move radially outward from the axis of the shunt **2200** in a hinge-like fashion, allowing the deformable elements **2229***a* to be outwardly disposed when deployed. The cuts **2222'** forming the deformable elements **2227***a* of the distal anchor **2229** are substantially longitudinal along the axis of the shunt **2200** allowing the distal anchor **2229** and/or distal portion **2202** of the shunt **2200** to maintain a suitable column strength and pushability through tissue during deployment at a target site.

FIG. **15**H illustrates exemplary patterns and dimensions of the cuts **2210** along the elongated body **2203** of the shunt **2200**. The cuts **2210** of the elongated body **2203** may have a variety of suitable patterns. The cuts **2210** and their patterns are preferably manufactured by laser cutting the elongated body **2203** of the shunt **2200**. Alternatively, the cuts **2210** and their patterns may be manufactured by etching or other suitable techniques. For example, with a laser oriented orthogonal to the longitudinal axis of the body **2203** and with a laser capable of holding body **2203** while rotating and advancing the body relative to the fixture, the laser can be activated and deactivated to form specific cut patterns in shunt body **2203**. The laser cutting of the elongated body **2203** creates 1.5 cuts **2210** per rotation of the body, having a cut balance of about 210° of rotation with laser on, and then 30° of rotation with laser off. Further, while the pitch of the cut pattern is approximately 0.0070" (0.1778 mm) in the embodiments of FIG. **15**H, each cut **2210** may have a variety of widths; for example 0.005" (0.12446 mm). Additionally, the pitch of the cut pattern may be varied. For example, the pitch of the cut pattern of the body **2203** proximately disposed to the proximal portion **2204** and/or to the distal portion **2202** of the shunt **2200** may be larger/wider than the pitch of the cut pattern along the middle section of the body **2203**, as shown in FIGS. **15**D-E . . . .

It should be appreciated that the above disclosed units are exemplary dimensions, angles and properties of the shunt **2200**, which are not intended to limit the embodiment of FIGS. **15**A-K.

As previously disclosed, embodiments of the disclosed shunts can include an anti-thrombotic coating on all or a portion of the exterior of the device, to minimize clotting in the IPS after shunt deployment. Such anti-thrombotic coatings may comprise phosphorylcholine (e.g., Lipidure® products available from NOF Corporation) or Heparin-based compositions (e.g., CBAS® Heparin Surface available from Carmdea AB). Anti-thrombotic coatings can also be applied to anchor **700** and/or elongate guide member **780** to further minimize the risk of clotting in the IPS during the shunt implant procedure.

FIG. **16** illustrates a delivery catheter **3300**, constructed according to embodiments of the invention. The delivery catheter **3300** (or distal most portion of the delivery catheter) can include an oversheath member **3300"** (e.g., a larger, concentric sheath that covers the outer diameter of the delivery catheter and/or the penetrating element). The oversheath **3300"** can translate longitudinally about the delivery catheter, and can be retracted proximally to expose the needle tip **3350"** for the penetration step of the procedure. The oversheath **3300"** of FIG. **16** is disposed over a delivery catheter **3304** and penetrating element advanced over a guide member **3308"**; the bands **3303"** located proximal of the penetrating element comprise radiopaque markings to confirm orientation of the penetrating element and assess penetration trajectory during a shunt deployment procedure. The oversheath member covers the penetrating element as the delivery system navigates through the patient's vasculature, thereby preventing inadvertent vessel punctures. The operator can position the distal portion of the oversheath adjacent or abutting the target site penetration along IPS wall **114** until the operator is ready to expose the penetrating element or advance the penetrating element through the tissue into the CP angle cistern **138**.

As described above, FIGS. **17**A-B illustrate an exemplary elongate guide member **780** for delivering of the anchor **700** at a target site, constructed according to the disclosed inventions. FIGS. **18**A-E illustrate another exemplary elongate guide member **780** for delivering of the anchor at a target site, constructed according to the disclosed inventions. The elongate guide member **780** of FIGS. **18**A-E includes a flat, rectangular cross-sectional profile, as described in FIG. **3**D and FIG. **11**. As shown in FIGS. **18**A-E, the elongate guide member **780** is coupled to the proximal portion **740** of anchor **700** via joint **744**, as previously described (e.g., directly or indirectly, fixedly or detachably coupled or the like). FIGS. **18**A-E illustrate exemplary dimensions and properties of the interface of the elongate guide member **780** with the anchor **700**, which are not intended to limit the embodiment of the interface disclosed herein. In the embodiments of FIGS. **18**D-E, the joint **744** between the anchor **700** and the elongate guide member **780** includes a rotatable element **745** configured to allow the elongate guide member **780** to rotate clockwise and/or counter-clockwise with respect to the anchor **700**. The independent rotation of the elongate guide member **780** relative to the anchor **700** via the rotatable element **745** at the joint **744** allows for the elongate guide member **780** to assume a desirable orientation through the curved portion of the IPS **102** during delivery and/or after deployment of the anchor **700**. For example, the anchor **700** may be delivered at a random orientation at the IPS **102**, yet the elongate guide member **780** would assume a desirable orientation by rotating (if needed).

FIGS. **19**A-I depict an embodiment of a delivery assembly **300** comprising delivery catheter **3304** and penetrating element guard or guard member **4000**. The guard member **4000** covers the penetrating element **3350** during navigation of the delivery catheter **3304** (FIG. **19**A) through the patient's vasculature to the target penetration site on IPS wall **114** and during withdrawal of delivery catheter **3304** after shunt deployment, thereby preventing inadvertent puncture or damage to other components of delivery assembly (e.g., guide catheter) and the patient's vasculature. As will be further described below, the clinician can actuate a pull wire **4010** to retract guard **4000** proximally and expose the penetrating element **3350** to the dura of IPS wall **114** prior to the penetration step of the shunt implant procedure and, optionally, then re-cover the penetrating element **3350** after the penetration step (e.g., after distal anchoring mechanism **229** of the shunt has been deployed). Radiopaque markers located on the guard **4000** and delivery catheter **3304** provide an indication of whether the guard has been retracted and penetrating element **3350** is exposed or the guard remains in a delivery configuration, covering the penetrating element **3350** for navigation through the patient's vasculature, as will be further described below.

With reference to FIG. **19**A, the distal portion **3344** of delivery catheter **3304** comprises penetrating element **3350** and a radiopaque marker **3354**. As previously described, delivery catheter **3304** includes a first lumen **3315** to accommodate elongate guide member **780** and a second lumen **3305** to accommodate a shunt **2200** (not shown). The guard member **4000** comprises a pull wire **4010**, the pull wire **4010** having a distal portion **4011** attached to a guard body **4000**, where the pull wire **4010** is configured to translate the guard body **4000** proximally or distally relative to the shunt delivery catheter **3304** so as to at least partially expose or cover, respectively, the penetrating element **3350**. The distal portion **4011** of pull wire **4010** is embedded or encased within guard **4000** (as will be further described below) and includes an attachment point **4011***a* (e.g., a weld) to radiopaque marker **4015** also embedded within guard **4000** (as will be further described below). The guard **4000** further comprises a first lumen **4020** configured to receive the penetrating element **3350** and allows the guard **4000** to retract proximally (direction of left-hand arrow d**2** in FIG. **19**A) over the penetrating element **3350** and distal portion of **3344** of delivery catheter and distally (e.g., to re-cover penetrating element **3350**, direction of right-hand arrow d**2** in FIG. **19**A) via pull wire **4010**. The enlarged circumference in the distal portion **3344** of delivery catheter **3304** at interface point **3315***a* where the elongate guide member **780** enters the first lumen **3315** of the delivery catheter prevents guard **4000** from retracting further proximally over the delivery catheter. Guard **4000** can advance distally, via pull wire **4010** and as will be further described below, to re-cover penetrating element **3350**. As shown in FIG. **19**A, the shunt delivery catheter **3304** includes a third lumen **3325** that extends throughout the length of the delivery catheter, from the distal portion **3344** to the proximal portion **3342**; third lumen **3325** accommodates pull wire **4010** of guard **4000**.

FIGS. **19**B and **19**C show cross section and perspective views, respectively, of penetrating element guard or guard member **4000**. FIG. **19**B depicts a guard member **4000** in a delivery configuration with respect to the distal portion **3344** of delivery catheter **3304** (represented by dashed lines in the figure), covering penetrating element **3350**. Penetrating element **3350** is positioned within lumen **4020** of the guard **400** and inside of radiopaque marker **4015** embedded or encapsulated within the walls of guard **4000** (as will be further described below). The guard member **4000** can be approximately 0.5" (1.27 cm) long or other suitable dimensions sufficient to cover penetrating element **3350** on the distal portion **3344** of the delivery catheter. The guard lumen **4020** is sized to allow guard **4000** to retract proximally over the penetrating element **3350** and distal portion **3344** of the delivery catheter, indicated by the direction of the left-hand arrow d**2** shown in FIG. **19**A. For example, the inner diameter of guard lumen **4020** can be approximately 0.0385" (0.09779 cm).

Marker **4015** comprises a cylindrical profile (as can be seen in FIGS. **19**B-D and **19**G) such that penetrating element **3350** can reside inside of marker **4015** and the guard first lumen **4020** as depicted in FIG. **19**A; the alloy material of marker **4015** shields the concentrically disposed penetrating element **3350** and can prevent the penetrating element from inadvertently puncturing through the guard **4000** when the distal portion of **3344** of delivery catheter **3304** bends as the clinician navigates the delivery assembly **300** through tortuous anatomy to the target penetration site along IPS wall **114**. The distal portion **4004** of the guard **4000** has a beveled/tapered edge, as shown in FIGS. **19**B and **19**C. The bevel/taper facilitates access to narrow or tortuous vasculature as the clinician navigates the delivery assembly distally beyond the inferior vena cava (e.g., to access and navigate through junction **118** of jugular vein **106** and IPS **102**). The guard **4000** may comprise a second lumen **4035** to accommodate elongate guide member **780** as shown in FIG. **19**C. The delivery assembly **300** comprising delivery catheter **3304** and guard **4000** can advance along the elongate guide member **780** distally, toward the target penetration site; that is, the guide member **780** passes through second lumen **4035** of the guard **4000** and lumen **3315** of delivery catheter **3304** to assist delivery catheter navigation through the patient's vasculature.

FIG. **19**D depicts the pull wire **4010** and radiopaque marker **4015** subassembly of guard **4000**. Pull wire **4010** can comprise PFTE-coated stainless steel or other suitable materials. The diameter of pull wire **4010** can range from about 0.003" to 0.012" (0.0762 mm to 0.3048 mm). While pull wire **4010** depicted in FIG. **19**B-D has a circular cross-sectional profile, other pull wire embodiments can include non-circular cross-sectional profiles (e.g., rectangular, crescent). The PTFE coating on pull wire **4010** increases the lubricity of the wire within the third lumen **3325** of delivery catheter **3304**, thereby facilitating smooth proximal and distal actuation of guard **4000** to expose and re-cover penetrating element **3350** (not shown in FIG. **19**D). Radiopaque marker **4015** can comprise platinum-iridium **90/10** alloy or other suitable materials that provide sufficient radiopacity and allow for a connection point **4011***a* between the marker and distal portion **4011** of pull wire **4010**. The inner diameter of marker **4015** can be 0.0385' or other suitable dimensions compatible with a guard lumen **4020** sufficient to accommodate the distal portion of delivery catheter **3344** and penetrating element **3350**. As shown in FIG. **19**D, the distal portion **4011** of pull wire **4010** does not include the PTFE coating depicted on the body portion of pull wire **4010**; the uncoated stainless steel distal portion **4011** of pull wire allows for a weld or other connection point **4011***a* to radiopaque marker.

FIGS. **19**E and **19**F show cross section views of the proximal portion **4002** and distal portion **4004**, respectively, of the guard member **4000**. As depicted in FIG. **19**E, marker **4015** and pull wire **4010** are embedded or encapsulated within the wall of guard **4000**. Guard **4000** can comprise polymeric materials such as polyether block amide (Pebax® available from Arkema Group), HTPE, PTFE, urethanes or the like. Pebax embodiments of guard **4000** can range from 27D to 70D hardness (e.g., Pebax 63D). The wall thickness of guard **4000** can vary depending on top-to-bottom orientation of the guard. The top portion of guard **4000** (represented by line A in FIG. **19**E) can range from about 0.002" to 0.006" (0.0508 mm to 0.1524 mm) or larger. The bottom portion of guard **4000** (represented by line B in FIG. **19**E) can range from about 0.008" to 0.014" (0.2032 mm to 0.3556 mm) or larger.

As previously disclosed and during the shunt implant procedure, an clinician can deploy an anchor **700** distal to a target penetration site along IPS wall **114**. Thereafter, the clinician advances a delivery assembly **300** comprising delivery catheter **3304** and penetrating element guard **4000** via elongate member **780** to the target penetration site. The radiopaque marking **3354** on the distal portion **3344** of the delivery catheter **3304** and radiopaque marking **4015** within guard **4000** provide reference points for the clinician to visualize the location of the delivery assembly and penetrating element **3350** at the target penetration site. When the clinician is prepared to penetrate IPS wall **114**, the clinician can pull the proximal end of pull wire **4010** proximally, which retracts guard **4000** proximally over the distal portion **3344** of delivery catheter (indicated by the direction of the left-hand arrow d**2** shown in FIG. **19**A) and exposes penetrating element **3350** from the delivery assembly **300**. Observing the transition of marker **4015** in guard **4000** proximally towards and/or until it abuts marker **3354** on the distal portion **3344** of the delivery catheter (e.g., in the direction of arrow d**2** shown in FIG. **19**A) confirms that guard **4000** actuated properly and penetrating element **3350** is exposed from the delivery assembly in the patient's vasculature. Conversely, after shunt implantation, the clinician can advance pull wire **4010** distally to re-cover penetrating element **3350** and confirm that the guard **4000** is in a delivery or withdrawal configuration (e.g., penetrating element not exposed in IPS **102** or jugular vein **106** lumens).

FIG. **20** depicts an alternate embodiment of penetrating element guard **4000**. For ease in illustration, like features of the penetrating element guard **4000** and delivery catheter **3304** shown in FIG. **20** have been given the same reference numerals from FIGS. **19**A-F. Guard **4000** comprises a guard **4000** having a full-length, "oversheath" configuration; that is, guard **4000** is a sheath that extends along the length of and over the delivery catheter **3304** disposed concentrically within guard lumen **4020**. Guard **4000** can be retracted proximally (direction of left-hand arrow D**2** in FIG. **20**), e.g., by a clinician pulling on the proximal portion of guard **4000** to uncover and expose a protected penetrating element **3350**. Optionally, guard **4000** can include a scored or weakened portion (e.g., indicated by dotted line d**1** in FIG. **20**) that splits or tears (e.g., along the longitudinal axis of the guard) to facilitate guard retraction.

Guard **4000** includes a second lumen **4035** that accommodates elongate guide member **780**. Lumen **4035** can extend from the distal portion or end of guard **4000** and include an exit port **4035***a* located in the distal portion of guard **4000**, as shown in FIG. **20**. As compared to the guard configuration described in connection with FIGS. **19**A-F, the guard configuration shown in FIG. **20** simplifies the design of the delivery assembly **300** by eliminating pull wire **4010** and a corresponding pull wire lumen **3325** in the delivery catheter **3304**.

FIGS. **21**A-M depict an alternate embodiment of delivery catheter **3304**. FIGS. **21**C and D show longitudinal side and cross section views, respectively, of delivery catheter **3304**. FIGS. **21**A and B show cross section views of delivery catheter **3304** at reference lines in FIG. **21**C, respectively, looking from the distal portion **3344** of the catheter towards the proximal portion. FIG. **21**I shows another longitudinal side view of the delivery catheter of FIGS. **21**A-M. FIGS. **21**F-M depict cross section views of delivery catheter **3304** at various points along the longitudinal axis corresponding to the reference line designations in FIG. **21**I.

With respect to FIGS. **21**C, D, and I, the depicted delivery catheter **3304** includes a beveled-needle penetrating element **3350** on the distal portion **3344** of the delivery catheter. The penetrating element **3350** can be fixed to the delivery catheter and, as depicted, is welded to reinforcing member **1345** (further described below). Delivery catheter includes three distinct radiopaque marker bands: a distal most marker **3354** located about the proximal portion of penetrating element **3350**, an intermediate marker **3354***a*, and proximal most marker **3345***b*. A first lumen **3315** in the delivery catheter accommodates elongate guide member **780** and lumen **3315** can include a polymeric liner **3306** material such as PTFE (FIG. **21**B) to increase the lubricity of the lumen and facilitate smooth motion of the delivery catheter **3304** over guide member **780**.

As depicted, first lumen **3315** has a rapid-exchange configuration and does not span the entire longitudinal axis of deliver catheter **3304**, although such a configuration is possible in other embodiments. Marker bands **3354***a* and **3354***b* reinforce the distal **3315***a* and proximal **3315***b* openings of lumen **3315**, as shown in FIGS. **21**A and **21**K-L. FIG. **21**D includes longitudinal dimensions along the length of delivery catheter **3304**, measured from the proximal portion of penetrating element **3350** to the distal opening **3315***a* of first lumen **3315** (0.16"/0.4064 cm), to the distal edge of marker band **3354***a* (**0.17**"/0.4318 cm), to the distal edge of marker band **3354***b* (7.95"/20.193 cm), to the proximal opening **3315***b* of first lumen **3315** (8"/20.32 cm), and to the proximal portion of delivery catheter **3304** (39.37"/100 cm). Further, delivery catheter **3304** includes a second lumen **3305** to accommodate a shunt and shunt pusher delivery assembly as disclosed herein. Second lumen **3305** includes a polymeric liner material **3306** as indicated in FIGS. **21**E, **21**E-**1**, **21**E-**2** to FIG. **21**M, such as PTFE.

The outer diameter of delivery catheter **3304** of FIGS. **21**A-M varies along the longitudinal axis. The cross section views of FIGS. **21**F-M, working from the distal most cross-section to the proximal most cross-section along the axis of delivery catheter **3304**, correspond to the reference lines shown in FIG. **21**I as follows: FIG. **21**J at reference line E-E in FIG. **21**I; FIG. **21**F at reference line F-F in FIG. **21**I; FIG. **21**K at reference line G-G in FIG. **21**I; FIG. **21**G at reference line H-H in FIG. **21**I; FIG. **21**L at reference line I-I in FIG. **21**I; FIG. **21**H at reference line J-J in FIG. **21**I; and FIG. **21**M at reference line K-K in FIG. **21**I. Each of FIGS. **21**A-B and F-M specify the maximum outer diameter along the longitudinal axis of the delivery catheter **3304** at the location of the particular cross section depicted, which varies depending on the longitudinal location of the cross section along the axis of the catheter (e.g., ranging from 0.036" to 0.046"/0.09144 cm to 0.11684 cm). FIGS. **21**K, **21**F, and **21**J depict a gradually tapering outer diameter in the distal portion of the delivery catheter **3304**, moving in the distal direction along the axis of the catheter (i.e., from 0.046" to 0.036"/0.11684 to 0.09144 cm), which facilitates access to tortuous anatomy and narrowings in the vasculature (e.g., junction **118** of jugular vein **106** and IPS **102**).

While FIGS. **21**A-M and the foregoing description reference a two-lumen delivery catheter **3304**, additional embodiments of the delivery catheter can include a third lumen (e.g., lumen **3325** of **19**A, FIGS. **29**A-D to accommodate, for example, a pull wire of a penetrating element guard **4000**, as further described below) and fourth lumen (e.g., lumen of to accommodate, for example, a second pull wire of a penetrating element guard **4000**, as further described below and shown in FIGS. **64**D-E).

Criteria for selecting a particular needle as the penetrating element **3350** of a delivery assembly **300** include bevel length, force required to penetrate IPS wall **114**, and needle wall thickness. Bevel length is inversely related to the puncture force required to penetrate IPS wall, though longer bevels can make navigation of delivery assembly **300** more difficult as compared to shorter bevels, particularly in tortuous anatomy, given that needles do not flex as the distal portion **3344** of the delivery catheter **3304** navigates through the vasculature. Lower puncture forces facilitate a smooth penetration step of the shunt implant procedure, as the penetrating element passes through IPS wall **114** into the subarachnoid space. Puncture force for candidate penetrating element embodiments can be assessed in vitro using a dura surrogate, e.g., DuraGuard® Dural Repair Patch available from Synovis Surgical Innovations, and force gauge as further described in U.S. patent application Ser. No. 14/929,066 filed on Oct. 30, 2015. Penetrating element embodiments comprising a needle configuration can have a puncture force of about 0.1 pounds-force or less. A thinner needle wall minimizes the gap between the anastomosis through IPS wall **114** and the outer surface of deployed shunt **2200**. Reducing this gap is clinically significant to minimize or eliminate venous blood from leaking from the IPS **102** or CS **104** through the anastomosis (e.g., between the penetration tract through IPS wall **114** and the outer surface of implanted shunt **2200**) into the subarachnoid space and, conversely, CSF leaking from the subarachnoid space into the IPS lumen.

FIGS. **22**A-F illustrate yet another exemplary shunt **2200'** constructed and implanted according to embodiments of the disclosed inventions. For ease in illustration and disclosure, the features, functions, and configurations of the shunt **2200'** that are the same as in the shunt of the present disclosure (e.g., FIGS. **15**A-J) and in the related application, are incorporated by reference herewith; the differences will be described in further detail below. The shunt includes an elongate body **2203** extending between the proximal **2204'** and distal **2202** portions and having a lumen. The body **2203** of the shunt includes selective cuts **2210** (e.g., kerfs, slots, key-ways, recesses, or the like) forming transition areas configured to vary the flexibility of the shunt **2200'**, such as, from the proximal portion **2203***a* (less flexible) to the distal portion **2203***c* (more flexible), as shown in FIGS. **22**A and **22**D-E. As better appreciated in the embodiment of FIG. **22**E, the proximal portion of the shunt further includes an anchoring mechanism **2227'** (i.e., proximal anchor), similar to the distal anchoring mechanism **2229** of the shunt **2200'** and previously described distal anchoring mechanism **2229**. The anchoring mechanisms **2227'** and **2229** include a plurality of respective deformable elements **2227***a*' and **2229***a* (e.g., arms) that are disposed radially outward in the deployed configuration of the shunt. As shown in FIGS. **22**A-B and **22**D-E, the proximal anchoring mechanism **2227'** further includes a proximal interlocking element **2227***d*' (e.g., eyelet, slot, groove, or the like) configured to interlock with corresponding interlocking elements **3336'**/**3336***b* of a pusher member. The proximal interlocking element is better appreciated in FIGS. **22**B, and **22**F. The anchoring mechanisms **2227'** and **2229** include radiopaque markers **2227***c*' and **2229***c* (e.g. annular, ring, angled-arrow marker or the like), which are shown as press flush in FIGS. **22**A-B.

FIGS. **22**A-G discloses exemplary dimensions, cut patterns, angles, configurations and/or properties of the shunt **2200'**, pusher member **3310'**, radiopaque markers **2227***c*', and the interlocking elements **2227***d*' and **3336'**. It should be appreciated that the disclosed dimensions, cut patterns, angles, configurations and/or properties are exemplary and not intended to limit these embodiments.

FIGS. **23**A-B and **24**A-F illustrate exemplary interfaces of the delivery catheter **304**, pusher member **3310'** and shunt **2200'**, according to embodiments of the disclosed inventions (e.g., FIG. **6**). The delivery catheter **304** may further comprise a hypotube providing suitable column strength and flexibility, as previously described in **12**A-C. FIGS. **23**A-B, the pusher member **3310'** and shunt are disposed within the delivery catheter lumen **305** and having their respective interlocking members **3336'**/**3336***b* and **2227***d*' engaged, as shown in FIGS. **23**A-B and FIGS. **24**A-B.

FIGS. **23**A-B illustrate the pusher member and shunt interface constrained within a delivery catheter **304** and/or the pusher member and shunt interface as if advanced out of the distal end opening of the delivery catheter and before the respective interlocking elements separate to release the shunt **2200'** from the pusher member **3310'**. Although, the respective interlocking members of the pusher member **3310'** and the shunt **2200'** are engaged in FIGS. **24**A-B, it should be appreciated that pusher member **3310'** and shunt **2200'** interface will disengage (e.g., pusher interlocking member **3336'**/**3336***a*-*b* outwardly expands or flares out) when the interface is no longer disposed within the delivery catheter lumen **305**, as shown in FIGS. **24**C-D.

FIGS. **24**E-F illustrate the pusher member **3310'** and shunt **2200'** interface where the interlocking members **3336'**/**3336***a*-*b* of the pusher member **3310'** outwardly expanded (e.g., flared out) and the shunt **2200'** is disengaged from the pusher member **3310'**. Further, the proximal anchoring mechanism **2227'** of the shunt **2200'** transitions from the delivery configuration (FIGS. **22**A-B and FIGS. **24**A-B) to the deployed expanded configuration (FIGS. **24**C-F).

FIGS. **25**A-O illustrate embodiments of the valve **2209"** constructed according to embodiments of the disclosed inventions. The shunt **2200** includes at least one valve **2209"**, as shown, for example, in FIGS. **15**A-B. The valve **2209"** regulates the rate of CSF flow through the shunt **2200**, while allowing flow of CSF only in one direction, i.e., from the distal portion **2202** located in the subarachnoid space to the proximal portion **2204** of the shunt **2200** located in the venous anatomy. The valve **2209** may be disposed at any suitable location within the body **2203** of the shunt **2200**, for example, proximate to or at the proximal portion **2204**, as shown in FIG. **15**A, to the distal portion **2202**, and/or in between said portions **2202**, **2204** (not shown). In certain embodiments, multiple valves can be disposed at different locations within the shunt **2200**.

The valve **2209"** can include a specific cracking pressure that, when met or exceeded by the positive pressure gradient between the subarachnoid space and venous system, opens the valve thereby facilitating CSF flow from the CP angle cistern into the jugular vein. For example, the cracking pressure of valve **2209** can be configured from about 3 mm Hg to about 5 mm Hg and/or when the differential pressure between the subarachnoid space and venous system reaches from about 3 mm Hg to about 5 mm Hg; however, other cracking pressures can be configured in valve **2209"** depending on the particular clinical needs of the patient and as low as about 0.5 mm Hg. Further, a desired rate of flow is in a range between 5 ml per hour to 20 ml per hour and more desirable between 10 ml per hour to 18 ml per hour under normal differential pressure conditions between the subarachnoid space and venous system. In some embodiments, the desired flow rate of CSF is approximately 10 ml per hour. In a 24-hour period, the flow of CSF through shunt **200** can be between 200 ml to 300 ml (e.g., 200, 225, 250, 275, or 300 cm^3).

The valve **2209** may have a variety of suitable features, and comprises a molded silicone element configured to be coupled to the shunt **2200** in fluid communication with the shunt lumen **2207** and/or liner **2212**. For example, the valve **2209'** of FIG. **25**E is a one-way valve **2209'** having a cylindrical body **2219** comprising a lumen **2237** and an end portion dome **2239**. The dome **2239'** comprises two or more leaflets **2290'** on the outer portion of the dome (FIG. **25**E) formed from cutting or slitting the part, and two or more leaflets **2290** on the inner portion of the dome **2239'** (FIG. **30**H) formed through the silicone molding process. The leaflets **2290** and **2290'** are configured to open the valve **2209'** facilitating CSF flow through the lumen **2237** into the jugular vein **106**. The outer leaflets **2290'** may be formed by creating cuts or slits in the molded silicone element of the valve **2209'**. As shown in FIGS. **25**E and **25**H, the valve **2209'** includes three inner leaflets **2290**, similar to a heart valve, molded into the valve. In addition, as shown in FIGS. **25**E and **25**H, the inner surface of the dome **2239** of valve **2209'** can include various tiling patterns to increase the available surface area that fluid flowing through the valve contacts to crack or open the valve from its resting or closed state. Other tiling patterns on the interior portion of the valve dome are possible to accommodate specific valve cracking pressures.

FIG. **25**A illustrates an alternate embodiment of valve **2209"** comprising a simple dome **2239"**. Two or more leaflets (not shown) can be created in the dome **2239"** in FIG. **25**A (e.g., by cutting or slitting with a trocar or blade, using an excimer laser, etc.) to achieve the desired cracking pressure of the valve (e.g., varying the extent of slitting across the surface of the valve dome and/or along the wall of valve **2209"**). FIGS. **25**B-D illustrate exemplary dimensions (in inches) of the valve **2209"**; exemplary dimensions of the dome thickness for molded silicone valves can also range from about 0.001" to 0.004" (0.0254 mm to 0.1016 mm). As shown in FIG. **25**B, the cylindrical body **2219** of embodiments of the valve **2209"** comprises at least two portions **2219***a* and **2219***b* with variable wall thickness, the portion **2219***a* comprises a larger wall thickness of approximately 0.006" (0.1524 mm) that the portion **2219***b* having a wall thickness of approximately 0.003" (0.0762 mm), as shown in FIGS. **25**B and **25**G for valve **2209'**. The thicker portion of the valve wall thickness can be used for handing the part during manufacturing or assembly steps, or can be an intended feature of the design (e.g., to allow incorporation into the shunt frame). The length of the portions **2219***a* of the valve **2209'**/**2209"** is approximately 0.030" (0.762 mm), while the length of the portions **2219***b* including the dome **2239'**/**2239"** is approximately to 0.040" (1.016 mm), as shown in FIGS. **25**B and **25**F. The dome **2239'** comprises a wall thickness with variable ranges shown in FIGS. **25**G and **25**I.

FIGS. **25**J-O illustrate alternative embodiments of valve **2209** including exemplary dimensions (in inches) having outer leaflets **2290'**. As shown in FIGS. **25**J-L, the valve **2209'"** includes three inner leaflets **2290** (FIG. **25**M) and three outer leaflets **2290'** (FIG. **25**N). FIG. **25**J illustrates a perspective view of an embodiment of the valve **2209'"** including the three sets of inner and outer leaflets **2290** and **2290'**, respectively. In addition, the exterior portion of the valve dome **2239"** includes three ribs **2293** as shown in FIGS. **25**J and **25**N; the outer ribs **2293** can increase the outer surface area of the valve **2209'"** to provide more robust backflow prevention of fluid through the valve (e.g., preventing backflow of venous blood through the valve into the subarachnoid space). FIGS. **25**K-O illustrate exemplary dimensions (in inches) of embodiments of the valve **2209'"** depicted in FIG. **25**J. Similarly to FIG. **25**C, the cylindrical body **2219** of the valve **2209'"** of FIG. **25**L comprises at least two portions **2219***a* and **2219***b* with variable wall thickness, the portion **2219***a* comprises a larger wall thickness that the wall thickness of the portion **2219***b*. For example, the wall thickness of portion **2219***a* can range from approximately 0.006" (0.1524 mm) to 0.001" (0.0254 mm), and the wall thickness of portion **2219***b* can range from approximately 0.003" (0.0762 mm) to 0.0003" (0.00762 mm). The length of the portions **2219***a* of the valve **2209** can range from approximately 0.030" (0.762 mm) to 0.005" (0.127 mm), while the length of the portions **2219***b* including the dome **2239** can range from approximately to 0.040" (1.016 mm) 0.003" (0.0762 mm), as shown in FIG. **25**K. The dome **2239'"** comprises a wall thickness with variable ranges shown in FIG. **25**O, though alternate embodiments can include thinner or thicker wall thicknesses, e.g., in the dome portion of the valve.

FIGS. **26**A-**28**Q illustrate alternative embodiments of the valve constructed according to embodiments of the disclosed inventions. The shunt includes at least one valve, as shown, for example, in FIGS. **15**A-C. The valve regulates the rate of CSF flow through the shunt, while allowing flow of CSF only in one direction, i.e., from the distal portion of the shunt located in the subarachnoid space to the proximal portion of the shunt located in the venous anatomy. Features, functions, and configurations of the valve of FIGS. **26**A-**28**Q that are the same as in the valve of the present disclosure (e.g., FIGS. **25**A-O) and in the related application, are incorporated by reference herewith, the differences will be described in further detail below. The valve may have a variety of suitable features, such as comprising a molded silicone element configured to be coupled to the shunt in fluid communication with the shunt lumen. For example, the valve **2209"** of FIGS. **26**A-D is a one-way valve having a cylindrical body comprising a valve lumen **2237** and an end portion dome **2239**. The valve **2209"** includes a transitional core **2236** (e.g., inner tapered surface of the dome **2239**), as better appreciated in the cross-sectional portion of the dome (FIG. **26**B). By contrast, the valve **2209"** of FIGS. **27**A-D include a non-transitional core **2235** (e.g., inner square or flat inner surface of the dome **2239**), as better appreciated in the cross-sectional portion of the dome **2239** (FIG. **27**B). Either valve **2239"**, having transitional (FIGS. **26**A-D) or non-transitional (FIGS. **27**A-D) cores **2236** or **2235**, respectively, include cuts, slits, holes, perforations or the like (FIGS. **28**A-Q) configured to open the valve **2209"** and allow for fluid communication facilitating CSF flow through the shunt when deployed in the target site.

FIGS. **28**A-Q illustrate exemplary valve cuts at the end portion dome **2239** of the valves **2209"** constructed according to embodiments of the disclosed inventions. The dome **2239** may be cut to include two or more leaflets **2290** formed from cutting or slitting, as shown in FIGS. **28**A, **28**C-E and **28**I. The leaflets **2290** may be similar to a heart valve, as shown in FIGS. **25**E and **25**H. Alternative the cuts at the end portion dome **2239** may not form leaflets, such as when linear cuts do not intersect **2291**, as better appreciated in FIGS. **28**B and **28**F-H. These non-intersecting cuts **2291** of the dome **2239** allow for opening of the valve **2209"** while also allowing the valve **2209"** to fully close.

FIG. **28**J-Q illustrate further exemplary valve cuts at the end portion dome **2239**. In contrast with the linear cuts of FIGS. **28**A-I, FIGS. **28**J-Q shows arcuate, circular-shaped, concave and convex cuts or the like, that may extend along the cylindrical body of the valve **2209"** forming two or more leaflets **2290**.

FIG. **29** illustrates valve embodiments that include an internal support member and exterior layer. For example, valve **2209** can include a relatively rigid internal support member **2219** comprising a gold (or other radiopaque metal or alloy), Nitinol, stainless steel, or polymeric hypotube (e.g., any of the polymers previously described herein or disclosed in the applications incorporated by reference). The internal lumen of the support member **2219** provides the shunt lumen **207** for a proximal portion of the shunt and can comprise the entire length of the shunt lumen in other embodiments. As shown in FIG. **29**, the support member **2219** can include one or more apertures (e.g., four apertures **2221** as shown in the figure). Exterior layer **2220** can include a silicone, polyurethane, or other suitable polymeric material hypotube or layer disposed concentrically over the internal support member **2219**. The proximal ends of internal support member **2219** and the exterior layer **2220** can be closed as depicted in the FIG. **29**. Exterior layer **2220** can include one or more slits **2241** (e.g., slit created by a blade or trocar) or apertures **2243** (e.g., apertures created by a laser that removes a portion of the layer material between the opposing edges of the aperture). The rotational or clocking orientation of the exterior layer **2220** and slits or apertures **2243** can be varied with respect to the location of the apertures **2241** of the internal support member **2219** (e.g., indicated by the "C" arrows in the FIG. **29**) to achieve a target cracking pressure in these alternate valve **2209**. As will be further described below, aspects of the valve **2209** of FIG. **29** allow CSF within shunt lumen **207** to flow through the apertures **2221** of the internal support member **2219**, between the respective outer surface of the internal support member and inner surface of the exterior layer, and out of the slit **2241** or aperture **2243** of exterior layer **2220**.

Where exterior layer comprises one or more slits **2241**, the opposing edges of the slit(s) provide a sealing interface to maintain the valve **2209** closed below a target opening or cracking pressure. When the shunt lumen **207** and/or internal support fill with CSF and meet or exceed the cracking or opening pressure of the valve **2209**, the one or more slits **2241** of the exterior layer **2220** open to allow CSF to flow from shunt lumen **207** and out from the valve **2209**. In backpressure conditions (e.g., venous blood pressure exceeds intracranial pressure), the slits **2241** seal to prevent blood from entering the shunt lumen **207**. Support member **2219** resists compression or collapse of the exterior layer in such backpressure conditions.

The relative sizing between internal support member **2219** and exterior layer **2220** (e.g., referenced as "AD" in FIG. **29**) can be optimized to target a valve cracking pressure, facilitate CSF flow from within internal support member **2219**/ shunt lumen **207** and through the exterior layer **2220** and out of the valve **209**, and prevent backlow. For example, in embodiments where exterior layer **2220** includes one or more slits **2241**, the difference between the outer diameter of internal support member **2219** and the inner diameter of exterior layer **2220** can be about 0.0001" to 0.005" (0.00254 mm to 0.127 mm). In embodiments where exterior layer **2220** includes one or more apertures **2243**, the outer diameter of the internal support member **2219** can be sized more closely to or slightly exceed the inner diameter of exterior layer **2220**. In such embodiments, the external and internal diameters of the internal support and exterior layer, respectively, can provide a sealing interface to prevent fluid flow below a target cracking pressure and in backpressure conditions; once CSF pressure within shunt lumen **207** and/or internal support member **2219** meet or exceed a target cracking pressure, CSF flows through the one or more apertures **2243** of the internal support and out through the one or more apertures **2243** of the exterior layer **2220**. In further embodiments comprising one or more slits in the exterior layer **2220**, the inner diameter of such exterior layer **2220** can match the outer diameter of the internal support member **2219**; in such embodiments, the exterior layer **2220** will seal against the internal support at the points where the respective inner and outer diameters touch below a target cracking pressure. Where the target cracking pressure is met or exceeded, CSF flows through the one or more apertures of the internal support **2219** and out through the one or more slits **2241** of the exterior layer **2220**.

FIGS. **30**A-G illustrate an alternative delivery catheter for delivering the shunt into a target site of a patient, constructed in accordance with embodiments of the disclosed inventions. For ease in illustration and disclosure, the features, functions, and configurations of the delivery catheter that are the same as in the catheter of FIGS. **10**A-K and in the related application, are incorporated by reference herewith; the differences will be described in further detail below. FIG. **30**A show perspective longitudinal side views at various points along the longitudinal axis of the delivery catheter. FIG. **30**B shows another perspective longitudinal cross-sectional views of the delivery catheter. The delivery catheter **3304** of FIGS. **30**A-E includes a penetrating element **3350** on the distal portion and a distinct radiopaque marker band **3354** proximately disposed to the penetrating element **3350**. The radiopaque marker band **3354** may be disposed in an angle with respect to the longitudinal axis of the catheter **3304** to indicate direction/orientation of the catheter distal portion **3344** during delivery of the shunt at the target site. The angled marker **3354** may further include directional features, such as arrow heads, or the like, as shown in FIGS. **31**A-G.

Further to the shunt lumen and the elongated guide member lumen, as shown in FIG. **10**C as **3305** and **3315** respectively, the delivery catheter of FIG. **30**A includes an additional lumen (FIGS. **30**D and **30**E) adjacently disposed to the shunt lumen. The additional lumen is configured to allow passage of the guard pull wire, the penetrating element guard, an additional penetrating element, tool, or any other suitable element.

The shunt delivery catheter **3304** includes a reinforcing member **1345** (FIGS. **30**A-B, FIGS. **30**F-G) configured to reinforce the catheter **3304** while providing a suitable balance between column strength and flexibility (e.g., "pushability" and "torqueability"). The reinforcing member **1345** is composed of suitable biocompatible and/or elastomeric materials such as, stainless steel, Nitinol® or the like. The reinforcing member **1345** includes a plurality of cuts **1330** (e.g., kerfs, slots, key-ways, recesses, or the like) selectively disposed in sections of the reinforcing member **1345** along length L_{20} of the delivery catheter **3304**, as shown in FIGS. **30**A-B, and FIG. **30**F. Alternatively, the cuts **1330** can be continuously disposed substantially along L_{20} (not shown). It should be appreciated that the cuts **1330** can have variable spiral cut patterns of kerf, pitch, cuts per rotation and cut balance along L_{20} or combinations thereof. Additionally, the reinforcing member **1345** of FIGS. **30**A-G includes an inner liner **1360** and an outer jacket **1365** (FIG. **30**B), as previously described and better appreciated in detail in FIG. **12**C. The inner liner **1360** and outer jacket **1365** are configured to cover—substantially completely or partially—the cuts **1330** of the reinforcing member **1345**, while maintaining the flexibility provided by the selective cuts **1330** and column strength afforded, in part, by the reinforcing member **1345**.

The distal portion of the delivery catheter **3344** of FIGS. **30**A-B and FIG. **30**F, further includes a stain-relief portion **3343** element proximately disposed to the penetrating element **3350** to avoid, minimize and/or resist kinking of the catheter **3304** at the transition area from the flexible portion of the catheter to the penetrating element, during penetration of the IPS wall and delivery of the shunt. Further, the selective cuts along the length of the delivery catheter are configured to provide a balance between column strength and flexibility of the catheter, such as, having a more rigid proximal portion to a more flexible distal portion (FIGS. **30**A-C).

FIGS. **31**A-G illustrate an alternative marker, constructed in accordance with embodiments of the disclosed inventions. The marker **3354** is composed of radiopaque material and may be formed by cutting a tubular element in an angle, as shown for example in angle A_{30} of FIG. **31**A. Additionally, the marker **3354** may include any other relative size, geometry or configurations (e.g., arrow head, different width of the band, asymmetric band, or the like) suitable to indicate direction and/or orientation of the element where the marker is disposed, such as for example, when the marker is disposed on the delivery catheter to indicate the direction of the penetrating element. FIGS. **31**D-E are detailed views of respective edges **3354'** and **3354"** of the marker of FIG. **31**C.

FIG. **32** illustrates a shunt constructed and implanted according to embodiments of the disclosed inventions. FIG. **32** illustrates yet another exemplary shunt **2200** constructed and implanted according to embodiments of the disclosed inventions. For ease in illustration and disclosure, the features, functions, and configurations of the shunt **2200** that are the same as in the shunt of the present disclosure (e.g., FIGS. **15**A-J, **22**A-**24**F) and in the related application, are incorporated by reference herewith; the differences will be described in further detail below. The implanted shunt **2200** of FIG. **32** shows three distinct zones; zone I (Distal) depicts the distal portion **2202** of the shunt having the distal anchoring mechanism **2229** engaging the dura mater IPS wall **114**, the arachnoid layer **115** and/or securing the shunt **2200** at the target site (e.g., subarachnoid space, CP angle cistern **138**), zone II (Mid) depicts the middle or body portion **2203** of the shunt disposed within the IPS **102** and zone III (Proximal) depicts the proximal portion **2204** of the shunt having the proximal anchoring mechanism **2227** engaging and/or securing the shunt in the venous system (e.g., IPS **102**, jugular vein **106**, and/or a jugular bulb **108**). In some shunt embodiments (e.g., FIGS. **53**, **54**A, **56**A-**58**F), zone III (Proximal) does not include an anchoring mechanism and the proximal portion **2204** of the implanted shunt is disposed in the IPS **102**, jugular vein **106**, and/or a jugular bulb **108**. The zone I (Distal) is configured to maintain a patent fluid inlet, zone II (Mid) is configured to accommodate a variety of IPS anatomies (e.g., length, curvature, width, or the like), maintain a patent fluid lumen (e.g., kink-resistant, non-thrombogenic, protein resistant, or the like), or alternatively function as an anchor within the IPS. Zone III is configured to minimize or prevent thrombus formation on the implanted shunt, maintain valve patency, and/or further maintain the valve **2209** separated from the vessel wall to prevent encapsulation (e.g., 2-3 mm away from the wall). FIGS. **33**A-**40**C illustrate exemplary embodiments of zones I-III of the shunt **2200** according to the disclosed inventions. It should be appreciated that the shunt **2200** constructed according to embodiments of the disclosed inventions may include any variety or combinations of zones I-III as disclosed herein and/or in the related application that are incorporated by reference herewith.

FIGS. **33**A-**40**C illustrate exemplary embodiments of zone I (Distal) of the shunt, according to the disclosed inventions. FIGS. **33**A-C illustrates a distal portion **2202** of the shunt **2200** including a double-malecot anchoring mechanism **2229** in a deployed expanded configuration. The double-malecot includes a proximal malecot **2229-1**, a distal malecot **2229-3** and a joint element **2229-2** (e.g., collar, band—FIGS. **33**A-B—, struts with hinge members—FIG. **33**C— or the like) disposed therebetween. The double-malecot is configured to expand into the deployed configuration engaging the arachnoid layer **115** at the CP angle cistern **138** and the dura layer **114** at the IPS **102**. The double-malecot configuration of the distal anchoring mechanism **2229** further secures the distal portion **2202** of the implanted shunt **2200**, while avoiding or minimizing distal or proximal migration/translation of the shunt **2200**. Additionally, the double-malecot distal anchoring mechanism **2229** may further include a liner **2229-4** (e.g., membrane, mesh, braid or other suitable permeable material or combinations thereof), as shown in FIGS. **33**B-C, configured to avoid or minimize the formation of thrombus.

FIGS. **34-35** illustrate distal portions **2202** of the shunt including a malecot-flarecot anchoring mechanism **2229** in a deployed expanded configuration. The malecot portion is configured to expand into the deployed configuration engaging the arachnoid layer **115** at the CP angle cistern **138** and the flarecot is configured to engage the dura mater **114** at the IPS **102**. The flarecot arms **2229***a* of the malecot-flarecot anchoring mechanism **2229** can flare out in the distal direction (e.g., towards the dura mater **114** in the implanted shunt), as shown in FIG. **34** or the flarecot arms **2229***a* can flare out in the proximal direction (e.g., towards the IPS **102** in the implanted shunt), as shown in FIG. **35**, or the flarecot arms **2229***a* may comprise a combination of the arms **2229***a* of FIGS. **34** and **35**. Similar to the double-malecot configuration, the zone I (Distal) embodiments of FIGS. **34-35** further secure the distal portion **2202** of the implanted shunt **2200**, while avoiding or minimizing distal or proximal migration/translation of the shunt.

FIG. **36** illustrates a distal portion **2202** of the shunt including a malecot anchoring mechanism **2229** in a deployed expanded configuration. The malecot anchoring mechanism further includes an annular element **2229-5** composed of expandable material (e.g., foam, swellable or the like). The annular element **2229-5** is configured to expand when disposed within an anastomosis channel formed by piercing the IPS wall **114** and arachnoid layer **115**, and further secure the shunt **2200** at the target site.

FIGS. **37-39**B illustrate distal portions of embodiments of the shunt **2200** including anchoring mechanisms **2229** in a deployed expanded configuration. The anchoring mechanism **2229** is composed of polymeric material, such as silicone, or any other suitable biocompatible non-metallic materials. The anchoring mechanism **2229** includes an expandable element that may have a spheroid, ellipsoid, obloid, diamond-like (FIGS. **37-38**), funnel-like (FIGS. **39**A-B) or any other suitable shape and dimension configured to anchor the shunt **2200** at the target site when expanded. In some embodiments, the distal anchoring mechanism **2229** includes one expandable element, as shown in FIGS. **37** and **39**A-B. In other embodiments, the distal anchoring mechanism includes at least two expandable elements and a portion therebetween, as shown in FIG. **38**. The distal anchoring mechanisms **2229** of FIGS. **37-39**B further include a one-way valve **2209**, which functions as the valves previously described herein (e.g., FIGS. **25**A-**28**Q).

FIGS. **40**A-C illustrate another embodiment of the distal portion of the shunt having an anchoring mechanism **2229** in a deployed expanded configuration. The anchoring mechanism **2229** of FIGS. **40**A-B includes a malecot and polymeric cover **2229-4**; the polymeric cover **2229-4** further includes a plurality of leaflets **2290**. In one embodiment, the polymeric cover **2229-4** is composed of urethane, and the leaflets **2290** are composed of silicone. It should be appreciated that any other suitable biocompatible materials may be used in the distal anchoring mechanisms **2229**. The leaflets **2290** are configured as one-way valve, and function as the valves previously described. The leaflets **2290** may further increase the functional valve area, as shown in FIGS. **40**A-B. The anchoring mechanism of FIG. **40**C includes a double-malecot and polymeric cover **2229-4** having a plurality of leaflets **2290** acting as one-way valve **2209**.

FIGS. **41**A-**48**B illustrate exemplary embodiments of zone II (Mid) of the shunt, according to the disclosed inventions. FIG. **41**A illustrates an elongated tubular member **2203** having a proximal portion (not shown), a distal portion **2203***a*, and a lumen **2207** (FIGS. **41**A-B) extending therebetween. FIG. **41**B is a cross-sectional view of FIG. **41**A. The elongated tubular member **2203** of FIGS. **41**A-B is configured to be compressed and/or stretch during delivery of the shunt **2200**. The elongated tubular member **2203** of FIGS. **41**A-B is composed of silicone and is formed by extrusion. In other embodiments, the elongated tubular member **2203** of zone II (Mid) of the shunt **2200** can be composed of any other suitable biocompatible polymeric material including, for example, polyurethane or silicone-polyurethane blend, and can be formed by any suitable technique.

FIG. **42**A illustrates the elongated tubular member **2203** of FIGS. **41**A-B having an embedded coil element **22031**. The coil element **22031** can be composed of any suitable polymeric, metallic material or combination thereof. The coil element **22031** provides reinforcement (e.g., increased column strength) and kink resistance to the zone II (Mid) of the shunt. FIG. **42**B is a cross-sectional view of FIG. **42**A.

FIG. **43**A illustrates the elongated tubular member **2203** of FIGS. **41**A-B having an embedded tubular element **22032**. The embedded tubular element **22032** can be composed of any suitable materials, such as, platinum, Nitinol®, gold or other biocompatible materials. The embedded tubular element **22032** provides reinforcement (e.g., increased column strength) and kink resistance to the zone II (Mid) of the shunt. Further, the embedded tubular element **22032** includes a plurality of cuts along the length configured to increase flexibility of the element. FIG. **43**B is a cross-sectional view of FIG. **43**A.

FIGS. **44**A-**48**B illustrate the elongated tubular member **2203** of FIGS. **41**A-B having one or more spine elements **22033**. The spine element **22033** can be composed of any suitable materials, such as, platinum, Nitinol®, gold or other biocompatible materials. The spine element **22033** is configured to provide reinforcement (e.g., increased column strength) and kink resistance to the zone II (Mid) of the shunt. In some embodiments, the spine element **22033** can be used as shunt shaping stylets. The spine element **22033** can be an elongated rod or cylindrical member (FIGS. **44**A-B, **46**A-B), an arcuate elongated member (FIGS. **45**A-B), a flat elongated member (FIGS. **48**A-B), or can have any other suitable configuration. In the embodiments of FIGS. **44**A-B, the spine element **22033** is disposed in the lumen **2207** of the tubular element, such as concentrically disposed (FIGS. **44**A-B) or laterally disposed (FIGS. **45**A-B). In the embodiments of FIGS. **46**A-**48**B, a plurality of spine elements **22033** is embedded in the tubular element **2203**. FIGS. **44**B-**48**B are a cross-sectional view of the respective FIGS. **44**A-**48**A.

FIGS. **49**A-B illustrate exemplary embodiments of zone III (Proximal) of the shunt according to the disclosed inventions. Additionally, FIGS. **49**A-B illustrate deployed shunts **2200** having previously disclosed zones I and II, in combination with zone III of the shunt that will be described below. As shown in FIGS. **49**A-B, the proximal anchoring mechanism **2227** includes an expandable member and having a bulb-like configuration. The proximal portion **2204** of the shunt further includes a valve **2209** proximally disposed to the anchoring mechanism **2227** (e.g., at the tip of the conical proximal end and/or the valve being formed by slits on the bulb-like anchoring mechanism). FIGS. **49**A-B are perspective views of the shunt; the shunt further having the elongated tubular member **2203** of FIGS. **41**A-B in zone II, and the malecot-flarecot anchoring mechanism **2229** of FIG. **35** in zone I.

FIGS. **50**A-C illustrate another exemplary embodiment of zone III (Proximal) of the shunt having a proximal anchoring mechanism **2227**. As shown in FIGS. **50**A-B, the proximal anchoring mechanism **2227** includes a spine composed of shape memory material, such as Nitinol®, or other super-elastic alloys, configured to form a loop when the shunt is deployed. The spine can be configured to adjust the direction of CSF outflow from the deployed shunt device. For example, as shown in FIG. **50**B, the spine is configured to form a coil in zone III (Proximal) of the shunt with CSF outflow antegrade to the venous blood flow of the IJV; the valve **2209** shown in the FIG. **50**B faces the direction of blood flow in the IJV. The proximal anchoring mechanism **2227** of FIGS. **50**A-B is configured to maintain valve patency and further maintain the valve **2209** separated from the vessel wall to prevent encapsulation. FIGS. **50**A-C are perspective views of the shunt **2200**; the shunt further having the elongated tubular member of FIGS. **45**A-B or **46**A-B in zone II, and a single malecot-liner distal anchoring mechanism in zone I, as better appreciated in FIG. **50**C.

FIGS. **51**A-C illustrate yet another exemplary embodiment of zone III (Proximal) of the shunt having a proximal anchoring mechanism **2227**. As shown in FIGS. **51**A-B, the proximal anchoring mechanism **2227** includes a plurality of spine elements **22033** composed of shape memory material, such as Nitinol®, or other super-elastic alloys, configured to form a coil when the shunt is deployed. Similar to the embodiments of FIGS. **50**A-B, the proximal anchoring mechanism **2227** of FIGS. **51**A-B is configured to maintain valve patency and maintain the valve **2209** separated from the vessel wall to prevent encapsulation. FIGS. **51**A-C are perspective views of the shunt; the shunt further having the elongated tubular member **2203** of FIGS. **46**A-B or **47**A-B in zone II, and the malecot distal anchoring mechanism **2229** of FIG. **36** in zone I.

FIGS. **52**A-C illustrate another exemplary embodiment of zone III (Proximal) of the shunt **2200**. As shown in FIGS. **52**A-B, the zone III (Proximal) includes the configuration of the elongated tubular element **2203** of zone II (Mid) of FIG. **41**A-B. FIGS. **52**A-C are perspective views of the shunt **2200**; the shunt having the elongated tubular member **2203** of FIGS. **41**A-B in zone **2**, and the anchoring mechanism **2229** of FIG. **38** in zone **1**. In the embodiments of FIGS. **52**A-C the one-way valve **2209** is disposed in the distal anchoring mechanism **2229**.

FIG. **53** illustrates the embodiment of zone III (Proximal) of the shunt **2200** of FIGS. **52**A-B having the distal anchoring mechanism **2229** of FIG. **40**C.

FIGS. **54**A-B illustrates the embodiment of zone III (Proximal) of FIGS. **52**A-B having the distal anchoring mechanism **2229** of combined FIGS. **36** with **39**A-B.

FIGS. **55**A-O illustrate an exemplary shunt implant procedure in a patient suffering from elevated intracranial pressure. Any of the foregoing shunt and delivery system embodiments described herein can be used in the following exemplary procedure. The clinician can obtain CT and/or MRI imaging (e.g., coronal, T**2**, thin cut MRI images with gadolinium contrast) studies of the patient's intracranial anatomy to ascertain the sizing and relative proximity between the patient's right IPS **102**R and left IPS **102**L, CP angle cistern **138**, arterial structures (e.g., basilar artery), and surrounding bony anatomy; such imaging can also be used to assess the volume of unobstructed CSF space of CP angle cistern **138** surrounding the left and right IPS channels relative to a target penetration site **5000** in an IPS **102** where an anastomosis will be made during the shunt implant procedure. The clinician can use this pre-procedure imaging to select one or more preferred shunt deployment locations along the first curved portion **102**A and/or second curved portion **102**B in the patient's right IPS **102**R and/or left IPS **102**L. To further illustrate the following exemplary procedure, the clinician selects the patient's right IPS **102**R and a target penetration site **5000** along the first curve **102**A of the IPS based on the pre-procedure MRI imaging study, as shown in FIG. **55**A.

The clinician gains access to the patient's venous vasculature through the patient's right femoral vein using an introducer kit (e.g., Micropuncture Introducer Set from Cook Medical of Bloomington, Indiana) and the Seldinger technique. The clinician then navigates a guide wire (e.g., 0.035" guide wire such as an 0.035" GLIDEWIRE from Terumo Interventional Systems of Somerset, New Jersey) and a guide catheter **307** (e.g., 6 Fr catheter such as 6Fr ENVOY Guiding Catheter from Codman Neuro of Raynham, Massachusetts) through the femoral vein access point, distally through the vena cava and into the right jugular vein. The clinician can position the distal end of the guide catheter **307** about the JV-IPS junction **118** as shown in FIG. **55**A, and in certain patient anatomies, the distal end of the guide catheter can access the proximal portion of the IPS **102**. Optionally, a shuttle sheath (e.g., 7Fr Flexor Shuttle Guiding Sheath from Cook Medical of Bloomington, Indiana) may be advanced through the patient's venous vasculature, prior to advancing the guide catheter **307**; the guide catheter **307** can then be advanced through the shuttle sheath lumen to the jugular vein or JV-IPS junction **118**. The shuttle sheath can provide additional support to the guide catheter, other catheter and guide wire components navigated to IPS **102** during the shunt procedure.

Then, the clinician accesses the right IPS **102**R and/or cavernous sinus **104** with a micro catheter **3307** and micro wire **3333** (FIGS. **55**B and **55**C). The micro catheter **3307** (e.g., an 0.027" micro catheter such as a Phenom 27 Catheter from Cathera, Inc. of Mountain View, California, an Excelsior SL-10 Micro catheter from Stryker Neurovascular of Fremont, California, or a Marksman Micro Catheter from Medtronic of Irvine, California, any of the 0.027" micro catheter embodiments disclosed in U.S. Provisional Patent Application No. 62/466,272) advances through the guide catheter lumen, and the micro wire (e.g., an 0.010", 0.014", or 0.018" guide wire such as a Synchro2 Guidewire from Stryker Neurovascular of Fremont, California) can pass through the micro catheter lumen. The clinician advances the micro wire **3333** and micro catheter **3307** through the JV-IPS junction **118** into the right IPS **102**R (e.g., the micro wire **3333** may be advanced distally and incrementally, followed by the micro catheter **3307** advancing distally and incrementally over the micro wire **3333**, repeating the wire and catheter advancement steps in serial fashion; the micro wire may be advanced to its distal location first with the micro catheter following thereafter in two separate advancements; or the micro wire and micro catheter can be advanced distally, simultaneously through the JV-IPS junction **118** and into the right IPS **102**R). The clinician can position the distal end of the micro catheter **3307** at a location distal to the target penetration site **5000** in IPS wall **114** along first curve **102**A of the right IPS **102**R as shown in FIG. **55**C. The clinician withdraws the micro wire **3333** from the micro catheter **3307**, leaving the distal opening **3317** of the micro catheter **3307** distal to the target penetration site **5000** in IPS wall **114** along first curve **102**A of the right IPS **102**R, as shown in FIG. **55**C.

The clinician then deploys an anchor **700** and guide member **780** in the distal portion of the right IPS **102**R in step **5020** of the procedure, which results in the anchor **700** secured in IPS **102**R, distal to the target penetration site along IPS wall **114** of the first curved portion **102**A of the right IPS **102**R as shown in FIG. **55**E. The clinician can load the anchor **700** and elongate guide member **780** into the proximal opening (not show) of the micro catheter **3307**. Using elongated pusher of FIGS. **13**, **14**A-E and by loading the proximal portion **784** of guide member **780** through the pusher lumen **3724** as previously disclosed, the clinician advances anchor **700** and guide member **780** distally through the micro catheter lumen until the anchor **700** reaches the distal opening **3317** of the micro catheter lumen as shown in FIG. **55**D. The elongated guide member **780** may be disposed within the lumen **3724** of the elongated pusher **3710** (FIGS. **13**, **14**A-E) for delivering the anchor **700** into the IPS **102**, while the proximal portion **784** of guide member **780** extends out the elongated pusher **3710** (e.g., out through the lumen opening **3726**' of handle **3722**), as previously described. A clinician can pinch or hold the proximal portion **784** of guide member **780** extending through the handle **3722** against the handle outer surface **3725** and then advance the handle **3722** and guide member **780** into a micro catheter to advance the anchor **700** distally. The clinician can then retract elongated pusher **3710** proximally over the proximal portion **784** of guide member **780** (i.e., by releasing the proximal portion **784** of guide member **780** pinched or held against the handle outer surface **3725**), and thereafter repeat the advancing and retracting acts until the anchor **700** reaches a desired location (e.g., distal end of micro catheter lumen). The use of the elongated pusher **3710** facilitates the anchor **700** delivery and navigation by leveraging the column strength of guide member **780**, as an alternative to having an anchor pusher member that extends at least the length of the micro catheter.

The clinician then positions the distal portion of the micro catheter **3307** (i.e., with anchor **700** and guide member **780** packed inside) about the location for anchor deployment, and withdraws the micro catheter **3307** proximally while holding the anchor **700** in place using guide member **780** and/or advances anchor **700** via guide member **780** distally through the distal opening **3317** of the micro catheter **3307** while holding the micro catheter **3307** in place until the anchor **700** emerges from the catheter lumen and expands against the walls of the sinus lumen. At this point of the procedure, a distal portion of guide member **780** such as joint **744** coupling the guide member and anchor **700**, can be disposed in the sinus lumen; the remainder of guide member **780** remains within the micro catheter lumen. If the clinician is satisfied with the anchor deployment location, he then withdraws the micro catheter from the patient, leaving behind the deployed anchor **700** with guide member **780** that extends proximally from the proximal portion of anchor **700** through the first curved portion **102**A and junction **118** as shown in FIG. **55**E, through the patient's venous vasculature and out of the patient via the femoral vein access point. Alternatively, he can recapture the deployed anchor **700** and guide member **780** into the micro catheter lumen and redeploy the anchor in the sinus lumen one or more times until he is satisfied with the anchor deployment location. Optionally, the clinician can use elongated pusher **3710** with micro catheter **3307** to facilitate anchor **700** recapture and redeployment in the sinus lumen.

To continue the procedure, the clinician introduces delivery catheter **3304** into the patient's vasculature via the femoral vein access point and navigates the catheter **3304** distally through the JV-IPS junction **118** (as shown in FIG. **55**F) to the target penetration site **5000** along IPS wall **114** of the first curved portion **102**A of the right IPS **102**R. The clinician can feed the proximal end of guide member **780** through the first lumen **3315** of delivery catheter **3304**, via distal opening **3315***a* and proximal opening **3315***b* of the first lumen. The clinician then advances delivery catheter **3304** over guide member **780**, through the femoral vein access point and tracks the delivery catheter **3304** distally, over the guide member **780** and through the patient's venous vasculature, until the distal portion **3344** of the delivery catheter **3304** is positioned about the target penetration site **5000** along IPS wall **114** of the first curved portion **102**A of the right IPS **102**R as shown in FIG. **55**G. While tracking the delivery catheter **3304** distally, the clinician can hold the guide member **780** stationary or pull proximally on the proximal portion **784** of the guide member **780** to facilitate advancement of the delivery catheter **3304** through the patient's venous anatomy. In addition, the clinician can rotate the delivery catheter **3304** while tracking distally over the guide member **780** to overcome any resistance, e.g., resistance encountered while tracking the catheter through JV-IPS junction **118** and/or into right IPS **102**R.

The clinician can confirm the orientation of the delivery catheter **3304** and the trajectory of penetrating element **3350** through IPS wall **114** into CP angle cistern **138** relative to the target penetration site **5000** using one or more of the previously disclosed imaging techniques. The clinician may use the distal **3354***a* and proximal **3354***b* markers located on the distal portion **3344** of the delivery catheter **3304** in this confirmation step. The markers will be visible under various imaging modalities used during the procedure (e.g., bi- or single-plane fluoroscopy). To the extent the clinician has created a 3D reconstruction of the patient's anatomy about the target penetration site **5000** (e.g., using 3D-rotational angiography or venography), the clinician can confirm the orientation and/or trajectory of the penetrating element **3350** by combining the fluoroscopy and 3D reconstruction using a 3D road mapping technique. Optionally, the clinician can use the 3D reconstruction data to create a window representing the target penetration site **5000**; the 3D window and live fluoroscopy can be overlaid with respect to each other to provide further guidance for the clinician to penetrate IPS wall **114** at target penetration site **5000**.

Then, the clinician retracts the penetrating element guard or guard member **4000** to expose penetrating element **3350** in the IPS **102** at the target penetration site along IPS wall **114** of the first curved portion **102**A of the right IPS **102**R as shown in FIG. **55**H. The clinician retracts the guard member **4000** by pulling proximally on pull wire **4010** while holding the remainder of delivery catheter **3304** in place. While retracting guard **4000** and using the previously disclosed imaging techniques, the clinician will observe marker **4015** in guard **4000** transition proximally towards and/or until it abuts or overlaps with distal marker **3354***a* located on the distal portion **3344** of delivery catheter **3304**. Again, the clinician can confirm the trajectory of penetrating element **3350** through the IPS wall **114** into CP angle cistern **138** using one or more of the previously disclosed imaging techniques before penetrating IPS wall **114**. If the clinician is unsatisfied with the trajectory of the penetrating element **3350** or perceived penetration site **5000** on IPS wall **114**, the clinician can adjust the location of the distal portion **3344** of delivery catheter **3304** until the clinician is satisfied that penetrating element **3350** will penetrate the IPS wall **114** at the target location along the first curved portion **102**A of the right IPS **102**R. When adjusting the location of the distal portion **3344** of delivery catheter **3304** the clinician can re-sheath penetrating element **3350** by advancing the penetrating element guard **4000** distally via pull wire **4010** and then unsheath penetrating element by retracting guard **4000** proximally before penetrating IPS wall **114**; this re-sheathing step can prevent inadvertent penetration or injury to the IPS walls that could occur if the penetrating element **3350** were uncovered or unprotected while the clinician repositioned delivery catheter **3304** in the IPS **102**.

With the penetrating element **3350** oriented along a desired trajectory at the target penetration along IPS wall **114**, the clinician advances delivery catheter **3304** distally so that penetrating element **3350** passes through the dura of IPS wall **114**, arachnoid layer **115**, and into the CSF-filled subarachnoid space of CP angle cistern **138** as shown in FIG. **55**I. The clinician can pull proximally on the proximal portion of guide member **780** or hold the guide member **780** in place while advancing delivery catheter **3304** distally to cause the penetrating element **3350** to penetrate the IPS wall **114**; these techniques allow the portion of delivery catheter **3304**, distal of the lumen opening **3315***a* to track along the target trajectory and off-axis from the path of guide member **780** through the first curved portion **102**A of the right IPS **102**R. The clinician stops advancing delivery catheter **3304** distally when the clinician is satisfied that penetrating element **3350** and second lumen **3305** of delivery catheter **3304** have accessed CSF of the CP angle cistern **138**; this can be confirmed via one or more of the previously disclosed imaging techniques, e.g., by 3D road mapping.

As an alternative method of confirming access to CP angle cistern **138**, the clinician can aspirate CSF through the penetrating element **3350** and second lumen **3305** of delivery catheter **3304** to confirm that the penetrating element **3350** passed through IPS wall **114** and arachnoid layer **115** to access CSF within CP angle cistern **138** (e.g., aspirated CSF denoted by arrow-head lines in FIG. **55**J). The clinician can use a syringe on the distal portion of handle (e.g., 10 cc syringe) to aspirate CSF proximally, through delivery catheter **3304**. The presence of clear CSF in the syringe can confirm a successful penetration through the IPS into the CP angle cistern **138**. If the clinician observes blood in the syringe, this can indicate that the penetrating element **3350** did not completely pass through IPS wall **114** or remained entirely within right IPS **102**R. If the clinician did not penetrate IPS wall **114**, the clinician can re-attempt to penetrate IPS wall **114** at the target site, attempt to penetrate IPS wall **114** at another target penetration site along the first curved portion **102**A of right IPS **102**R, attempt to penetrate IPS wall **114** along the second curved portion **102**B of right IPS **102**R as will be further described below, or abort the procedure.

After confirming that the penetrating element **3350** passed through IPS wall **114** and arachnoid layer **115** to access CSF within CP angle cistern **138**, the clinician advances pusher member **3310** distally to advance shunt **200** distally from the lumen **3305** of delivery catheter **3304** until the distal anchoring mechanism **229** of the shunt deploys in CP angle cistern **138** in step **5050** of the procedure as shown in FIG. **55**K. The clinician can confirm that the distal anchoring mechanism **229** of the shunt deployed in the cistern by observing a radiopaque marking(s) on a distal portion of the shunt as it emerges from the catheter into the subarachnoid space, using one the previously disclosed imaging techniques (e.g., by using live fluoroscopy to observe the RO makings in the distal portion of the shunt transition from a delivery configuration to a deployed configuration as described in connection with FIG. **55**C). By pulling shunt pusher **3310** proximally (and, optionally, simultaneously pulling delivery catheter **3304** proximally), the clinician fully expands the distal anchoring mechanism **229** against arachnoid layer **115** in CP angle cistern **138**.

The clinician continues deploying shunt **200** across the penetration tract in IPS wall **114** and in the right IPS **102**R in step **5055** of the procedure as shown in FIG. **55**L. By holding shunt pusher member **3310** in place while withdrawing delivery catheter **3304** proximally, shunt **200** emerges from the delivery catheter lumen **3305** and deploys in the lumen of IPS **102**R. At this point in the procedure, the proximal portion of shunt **200** and, if included on the particular embodiment of shunt **200** being deployed, proximal anchoring mechanism **227** on the shunt remain inside lumen **3305** of delivery catheter **3304**; the remainder of the shunt is deployed in the CP angle cistern and right IPS **102**R.

The clinician finishes deploying shunt **200** in step **5060** of the procedure by deploying proximal anchoring mechanism **227** of shunt **200** about the JV-IPS junction **118** or in jugular vein **106** as shown in FIG. **55**M. Again, by holding shunt pusher member **3310** in place while withdrawing delivery catheter **3304** proximally, shunt **200** emerges from delivery catheter lumen **3305**. As the proximal anchoring mechanism **227** and interlocking elements **229** on the distal portion of the shunt pusher member **3310** emerge from within the delivery catheter lumen **3305**, the shunt pusher member and shunt separate or disconnect, thereby releasing shunt **200** from pusher member **3310**. The clinician, optionally, can pause the shunt deployment step before the shunt completely releases from the interlock (or the self-expanding distal end portion of the shunt delivery shuttle disclosed herein) of pusher member **3310** by holding delivery catheter **3304** in place (e.g., by not withdrawing delivery catheter **3304** proximally) to confirm that he is satisfied with the shunt deployment location in the patient before completely releasing shunt **200** from delivery catheter **3304**. In embodiments of shunt **200** that do not include a proximal anchoring mechanism **227**, step **5060** is completed in substantially the same manner, with shunt **200** releasing from the shunt delivery shuttle **4316** and proximal portion of shunt deployed in the JV.

In the next step **5065** of the procedure, the clinician removes delivery catheter **3304** from the patient by withdrawing it proximally through the venous vasculature and out of the patient at the femoral vein access point. Optionally, the clinician holds guide member **780** in place while withdrawing delivery catheter **3304** proximally to ensure that anchor **700** does not migrate proximally through IPS **102**R and interfere with deployed shunt **200**.

The clinician recaptures anchor **700** into the micro catheter and removes the anchor from the patient via the femoral vein access point in step **5070** of the procedure. By feeding the proximal portion of guide member **780** through the micro catheter lumen, the clinician can track the micro catheter distally over the guide member, around proximal anchoring mechanism **227** (if present) of the shunt deployed in the jugular vein **106** or JV-IPS junction **118**, until the distal end of the micro catheter reaches the joint **744** between the guide member and anchor. He can then further advance the micro catheter distally and/or hold stationary or pull guide member **780** proximally to transition the anchor from its deployed or expanded configuration in the sinus lumen to its compressed configuration within the micro catheter lumen as shown in FIG. **55**N. With the anchor compressed in the micro catheter lumen, the clinician withdraws the micro catheter and anchor from the patient proximally, through the venous vasculature and out of the femoral vein access point. Thereafter, he withdraws the guide catheter from the patient.

The deployed shunt **200** (shown in FIG. **55**O) and valve **2209** provide a one-way flow conduit to drain excess CSF from the patient's subarachnoid space into the jugular vein, thereby relieving the patient's elevated intracranial pressure. The arrows in FIG. **55**O depict the direction of CSF flow from the CP angle cistern **138** into the shunt lumen **207**, through valve **2209**, and into jugular vein **106**.

If in steps **5040** or **5045** of the procedure the clinician is unsuccessful at penetrating IPS wall **114** at the target penetration site along the first curved portion **102**A, he can continue the procedure by attempting to penetrate IPS wall **114** along the second curved portion **102**B of right IPS **102**R (e.g., as shown in FIG. **2**C). For example, in certain patient anatomies, an overhang of the petrous bone can prevent penetrating element **3350** from passing through IPS wall **114** into CP angle cistern **138**. The presence of this bony overhang can be confirmed during the shunt implant procedure by using one or more of the previously disclosed imaging modalities. The clinician can then continue the procedure by re-sheathing penetrating element **3350** with penetrating element guard **4000**, and advancing delivery catheter **3304** distally over guide member **780** until the distal portion of delivery catheter **3304** is positioned at a target penetration site along the second curved portion **102**B of right IPS **102**R. Optionally, the clinician can rotate delivery catheter **3304** from about 45 to 180 degrees while tracking distally from the first curved portion **102**A toward the second curved portion **102**B in IPS **102**R; by rotating the delivery catheter, the clinician can orient penetrating element **3350** such that further distal advancement of delivery catheter **3304** will advance penetrating element **3350** through IPS wall **114** at a target penetration along the second curved portion **102**B of right IPS **102**R. The clinician can continue the procedure and deploy shunt **200** through IPS wall **114** along the second curved portion **102**B of right IPS **102**R as previously described in steps **5030**-**5070** of the procedure.

Embodiments of shunt **200** that have been deployed in IPS **102** can be retrieved using a minimally invasive retrieval procedure guided by one or more of the imaging methods previously disclosed. The clinician can advance a guide catheter through the patient's vasculature (e.g., from a femoral vein access point in the patient) to the JV-IPS junction **118**. The guide catheter can be advanced until the proximal end of the catheter is proximate to the proximal end of shunt **200** deployed in the JV or further advanced until the proximal portion of the shunt **200** is contained within the distal portion of the guide catheter lumen. The clinician can then navigate a micro catheter (e.g., any of the 0.027" micro catheter embodiments previously disclosed) through the guide catheter until the distal opening **3317** of the micro catheter is proximate to the proximal end of the deployed shunt. An anchor **700** with elongate guide member **780** is then translated through the micro catheter, for example, using the elongated pusher **3710** and corresponding method of use as previously disclosed. The clinician can deploy anchor **700** from the distal opening **3317** of micro catheter **3307** and adjust the location of the expanded anchor **700** within the JV (and/or guide catheter lumen) until the proximal portion of the shunt is contained within the lumen of anchor **700** and/or the proximal portion of the shunt **200** has passed through one of the cells of anchor **700**. The clinician then re-sheaths the anchor **700** into the micro catheter **3307**, thereby compressing the proximal portion of shunt **200** within anchor **700** inside the micro catheter. The clinician can then withdraw the micro catheter proximally until the distal anchoring mechanism **229** of the shunt in CP angle cistern **138** collapses and passes through IPS wall **114**. The clinician can further withdraw the micro catheter into the guide catheter lumen and continue withdrawing the micro catheter from the patient to complete the shunt retrieval procedure. The retrieval procedure can also be completed using commercially available thrombectomy devices or embodiments of encapsulating shroud XXXX in addition to the anchor **700** as described above. After shunt retrieval, for example, to prevent bleeding into the CP angle cistern **138** through the penetration tract in IPS wall **114**, the clinician can temporarily deploy a balloon in the IPS to stop bleeding, deploy a covered stent in the IPS at the penetration site, or embolize that portion of the IPS using commercially available embolization devices (e.g., coils, particles, foam, adhesives).

FIGS. **56**A-E illustrate an alternate embodiment of shunt **2200**. Shunt **2200** includes a distal anchoring mechanism **2229** (i.e., malelcot), as well as a retaining element **2230** comprising a radiopaque material, which element will be further described below. Distal anchoring mechanism **2229** includes arms or tines **2229***a* comprising a hinge, living joint, or the like **2229***b*, as previously described herein. The shunt **2200** further comprises a shunt body **2203**, CSF lumen **2207**, and a one-way valve **2209** located in the proximal portion **2204** of the shunt.

The shunt body **2203** can have an elongate cylindrical configuration as depicted in FIG. **56**A and extend between the distal **2202** and proximal **2204** portions of the shunt. Shunt body comprises CSF lumen **2207**, e.g., as illustrated in the cross-section views of FIGS. **56**C-D. Shunt body **2203** can include an elastomeric polymer(s) suitable for implant applications including, but not limited to, silicone, polyurethane, polycarbonate urethane, thermoplastic polyurethane, aromatic or aliphatic polycarbonate thermoplastic polyurethane, silicone/polyurethane blends (e.g., thermoplastic silicone polycarbonate polyurethane comprising 20% silicone copolymer), or polyurethane silicone blends (e.g., polyurethane silicone copolymer). The durometer of the elastomer shunt body **2203** can range from about 15A to about 80A; for a silicone-based shunt body, the durometer can range from about 15A to about 80A, and for a urethane-based shunt body, the durometer can range from about 55A to about 80A. A shunt body **2203** comprised of an elastomeric polymer(s) advantageously resists thrombus formation on the portions of the implanted shunt in the blood flow of the IPS and jugular vein. Optionally, shunt **2200** can include an anti-thrombotic coating to prevent thrombus formation including, but not limited to, heparin-based or phosphorylcholine-based anti-thrombotic coatings. To further prevent thrombus formation, the length of shunt body **2203** can be configured such that the proximal portion **2204** and valve **2209** are located proximal to the IPS-JV junction **118** (e.g., by 0.25" or more) when implanted in the patient's vasculature; junction **118**, a location where the IPS and JV blood flows intersect, can experience more turbulent blood flow and have a higher risk for thrombus formation on an implant and valve portion placed in the junction as compared to a location where the proximal portion of the shunt and valve are placed more proximally in the jugular vein, away from junction **118**.

FIG. **56**C illustrates a cross section of shunt **2200**. The cross section of shunt body **2203** includes a shunt body wall thickness "W" in FIG. **56**C. The wall thickness of an elastomer shunt body **2203** can range from about 0.001 inch to about 0.010 inch. The diameter of the CSF lumen **2207** of shunt **2200** can range from about 0.010 inch to about 0.020 inch. The outer diameter of shunt body **2203** can range from about 0.006 inch to about 0.040 inch. The length of shunt body **2203** can range from about 0.25" to 3.0" (6.35 mm 76.2 mm) to or more.

FIGS. **56**B-D illustrate distal portion **2202** of shunt **2200**. With reference to FIG. **56**B, retaining element **2230** comprises a radiopaque material (e.g., gold or other radiopaque material disclosed herein) and the distal portion **2207***a* of CSF lumen **2207** (further described herein). Anchoring mechanism **2229** can include a radiopaque marker located in the distal collar **2229***c*. When shunt **2200** is deployed from a shunt delivery catheter, anchoring mechanism **2229** transitions (e.g., self-expands) from a compressed configuration within the delivery catheter (e.g., denoted by the dotted line portion “C” marked on FIG. **56**B) to its open or deployed configuration shown in FIG. **56**B, during deployment, the clinician can observe the marker of distal collar **2229***c* move toward the radiopaque retaining element **2230** to confirm that the distal anchoring mechanism **2229** has properly transitioned to its deployed state in CP angle cistern **138**.

FIGS. **56**C-D illustrate cross sections of the distal portion **2202** of shunt **2200** and the connection between distal anchoring mechanism **2229** and shunt body **2203** using one embodiment of a retaining element **2230**. Retaining element **2230** includes a lumen that forms the distal or CSF inflow portion **2207***a* of CSF lumen **2207** of the shunt and embodiments can have the same range of internal diameters as described above for CSF lumen **2207** of shunt body **2203**. Retaining element **2230** further includes a tapered portion **2233** to accommodate a curved portion of distal anchoring mechanism arms **2229***a* when the distal anchoring mechanism **2229** is in a compressed or delivery configuration; tapered portion **2233** also prevents retaining element **2230** from slipping proximally through the proximal portion **2229***e* of distal anchoring mechanism **2229** (e.g., during assembly).

The distal portion **2203***a* of shunt body **2203** is secured within the distal anchoring mechanism **2229**. As shown in FIGS. **56**C-D, distal portion **2203***a* of shunt body **2203** is compressed between the outer surface of retaining element **2203** and inner surface of the proximal portion **2229***e* of distal anchoring mechanism **2229**. For example, distal portion **2229***e* of distal anchoring mechanism **2229** can be compressed (e.g., crimped, swaged) over the distal portion **2203***a* of the shunt body and retaining element **2230**. Further, retaining element **2230** can include retaining features **2266** (e.g., circumferential threads as shown in FIGS. **60**C-D, barbs, tines, hooks, or the like) to secure the distal portion **2203***a* of shunt body **2203** over retaining element **2230** and within the proximal portion **2229***e* of distal anchoring mechanism **2229**.

FIG. **56**E shows proximal portion **2204** of shunt **2200**. Proximal portion **2204** includes a one-way valve **2209**. Valve **2209** comprises a slit valve configuration with a single slit **2241** aligned with the longitudinal axis of shunt body **2203**. This alignment can advantageously resist thrombus formation when implanted as it is also aligned generally with the direction of blood flow through the jugular vein and minimizes blood turbulence across the surface of proximal portion **2204** of the shunt. Proximal portion **2204** further includes a radiopaque marker **2227***c*, the marker may be disposed between a proximal plug **2207***c* and the valve **2209**, or the plug **2207***c* may include radiopaque materials. The radiopaque marker **2227***c* is configured to assist shunt visualization in a patient during follow up clinical visits. The proximal plug **2207***c* is configured to close the proximal opening of the lumen **2207** of the shunt **2200**.

Embodiments of valve **2209** can include one slit **2241** (e.g., as shown in FIGS. **29** and **56**E) or multiple slits **2241** located around the circumference of shunt body **2203** to achieve a desired opening or cracking pressure for the valve and/or target CSF flow rate at a nominal differential between ICP and venous blood pressure (e.g., any of the opening or cracking pressures described herein, any of the CSF flow rates described herein). The slit **2241** can be orthogonal to the surface of shunt body **2203** (e.g., as shown in FIGS. **29** and **56**E) or angled relative to such surface. Each slit **2241** can range from about 1 to 3 mm, or longer. Slit **2241** can be located in the proximal portion **2204** of shunt **2200** (e.g., as shown in FIG. **56**E) or located more distally or proximally (e.g., extending to the proximal end of shunt **2200** and/or into plug **2207***c* described below). With a cylindrically configured shunt body **2203**, the hoop strength of shunt body **2203** about slit **2241** prevents backlow of fluid (e.g., blood) through valve into CSF lumen **2207**; for example, the valve remains closed and does not allow blood to leak into CSF lumen **2207** when venous blood pressures on the exterior of the shunt elevate above CSF pressure in the shunt lumen **2207** and intracranial compartment (e.g., CP angle cistern **138**). Indeed, embodiments of valve **2209** have demonstrated backflow prevention with simulated venous blood pressures exceeding intracranial pressures by more than 175 mm Hg.

The proximal portion of CSF lumen **2007** can include a plug **2207***c* to close CSF lumen **2207** at its proximal end. Plug **2207***c* can comprise the same elastomeric material of shunt body **2203** or any of the other polymeric materials disclosed herein. Shunt **2200** can also include a radiopaque marker in the proximal portion of the shunt body **2203**. Plug **2207***c* can be doped with a radiopaque material (e.g., barium sulfate, tantalum, or the like) or plug **2207***c* and/or proximal portion **2204** of the shunt can include a marker band comprising any of the radiopaque materials disclosed herein (e.g., a marker can be embedded in plug **2207***c*, shunt body **2203**, or fixed thereto). The plug **2207***c* can have an atraumatic configuration (e.g., rounded end), as shown in FIG. **56**E, or a more elongate tapering configuration, or be squared off with respect to the longitudinal axis of shunt body **2203**.

FIGS. **57**A-D illustrate the connection between distal anchoring mechanism **2229** and shunt body **2203** with an alternate embodiment of retaining element **2230**. For ease in illustration and disclosure, the features, functions, and configurations of the shunt that are the same as in the shunt of the present disclosure (e.g., FIGS. **56**A-E) are incorporated by reference herewith; the differences will be described in further detail below. Retaining element of FIG. **57**A comprises a cylindrical element that forms the distal or CSF inflow portion **2207***a* of CSF lumen **2207** of shunt **2200**, as illustrated in the cross-section views of FIGS. **57**C-D. Retaining element **2230** can comprise titanium, stainless steel, Nitinol, or other super-elastic alloys. Retaining element **2230** can be connected to the proximal portion **2229***e* of distal anchoring mechanism **2229** (e.g., weld or adhesive placed through one or more openings **2229***d* in the distal anchoring mechanism **2229**). A cylindrical marker band **2240** can be swaged over the distal portion **2203***a* of shunt body **2203** and retaining element **2230** to secure the connection between the shunt body and distal anchoring mechanism. The distal collar **2229***c* of anchoring mechanism **2229** can include a radiopaque marker (not shown in FIG. **57**A-D). When shunt **2200** is deployed from a shunt delivery catheter, anchoring mechanism **2229** transitions (e.g., self-expands) from a compressed configuration within the delivery catheter (e.g., denoted by the dotted line portion "C" marked on FIG. **57**C) to its open or deployed configuration shown in FIG. **57**B; during deployment, the clinician can observe the marker of distal collar **2229***c* move toward the radiopaque marker band **2240** to confirm that the distal anchoring mechanism **2229** has properly transitioned to its deployed state.

Shunts comprising an elastomeric body **2203** (e.g., shunt **2200** of FIGS. **56**A-**58**F) can advantageously compress and elongate to facilitate translation through a delivery catheter lumen in a deployment procedure. For example, shunt body **2203** can compress radially up to about 80% (e.g., such that compressed shunt diameter is about 20% of its resting diameter). Further, shunt body **2203** can extend, stretch, or elongate longitudinally up to about 400% of its resting length. The compression and elongation features of shunt body **2203** can be leveraged to maintain a relatively smaller profile (e.g., outer diameter) of a delivery catheter and facilitate delivery catheter access and navigation and shunt implantation through narrow and/or tortuous vasculature.

FIGS. **58**A-F illustrate an embodiment of shunt **2200** that includes the connection between distal anchoring mechanism **2229** and shunt body **2203** with an retaining element **2230** illustrated in FIG. **57**A-D. FIGS. **58**A-F further include the valve **2209**, marker **227***c* and proximal plug **2207***c* of FIG. **57**A-D. As shown in FIGS. **58**C-F, the distal collar **2229***c* of distal anchoring mechanism **2229** includes a radiopaque marker band **2240** to confirm that the distal anchoring mechanism **2229** has properly transitioned from a compressed configuration in the delivery catheter lumen to a deployed configuration in CP angle cistern **138**.

FIGS. **59**-**63**B illustrates an embodiment of a shunt delivery shuttle **7000** for translating and deploying a shunt **2200** (e.g., embodiments of shunt **2200** illustrated in FIGS. **56**A-**58**F) through the second lumen **3305** of a delivery catheter **3304** (e.g., any of the delivery catheter embodiments disclosed herein including the delivery catheter illustrated in FIG. **64**A-E). The shunt delivery shuttle **7000** includes a distal shuttle portion **7016** (e.g., mesh, braid, shroud, stent-like, funnel-like, tubular body, or other configurations), coupled to an elongate proximal pusher **7012** (e.g., wire or elongated pushing member) via a junction **7014**. The distal shuttle portion **7016** of the shunt delivery shuttle **7000** comprises a proximal portion **7016***a* and a distal portion **7016***b*, having a lumen **7018** extending therebetween. The distal shuttle portion **7016** of the shunt delivery shuttle **7000** is configured to receive, retain, push and/or shuttle the shunt **2200**. As illustrated in FIGS. **59**A, **61**A, **62**A-C and **63**C, the proximal portion **7016***a* of the distal shuttle portion **7016** tapers toward junction **7014**.

The distal shuttle portion **7016** of the shunt delivery shuttle **7000** can comprise a self-expanding braid, and is shown in an expanded configuration in FIG. **59**. The distal shuttle portion **7016** is configured to receive shunt **2200** (e.g., within the lumen **7018**) and is configured to compress and elongate (e.g., FIG. **63**A-B) suitable for translation within the second lumen **3305** of the delivery catheter for translating the shunt **2000** through the catheter, into the implantation site of a patient. With a lined lumen (e.g., PTFE-lined second lumen of delivery catheter **3304**), the distal shuttle portion **7016** of the shunt delivery shuttle **7000** facilitates smooth transition of an elastomeric shunt **2200** through the delivery catheter. The expanded or resting diameter of distal shuttle portion **7016** of the shunt delivery shuttle **7000** can range from about 0.5 mm to about 6 mm. The compressed length of the shunt delivery shuttle **7000** (e.g., when compressed in a delivery catheter lumen) can range from about 0.25" to 3.0" (6.35 mm 76.2 mm) or more.

The distal shuttle portion **7016** of the shunt delivery shuttle **7000** includes multiple filaments **7020** that are weaved to form the braid structure, as illustrated by the inset of FIG. **59**A. Filaments can comprise Nitinol (e.g., heat-set), stainless steel, or a polymer (e.g., PTFE, HDPE, PET, PEEK, Kevlar). Embodiments of the distal shuttle portion **7016** of the shunt delivery shuttle **7000** can include 8 to 144 filaments. Filaments **7020** of the distal shuttle portion **7016** can have round or non-round cross-sections; round cross-section filaments can have a diameter from about 0.0002 inch to about 0.005 inch. Filaments **7020** can be cut in the distal portion **7016***b* of the distal shuttle portion **7016** (e.g., as illustrated in FIG. **59**), rounded, or braided back proximally toward the distal shuttle portion **7016** midsection to create a more atraumatic profile for the distal portion **7016***b* of the distal shuttle portion **7016**.

The elongate proximal pusher **7012** can have a round or non-round cross-sectional profile. Embodiments of elongate proximal pusher **7012** with a round cross section can have a diameter of about 0.0006 to about 0.030 inch. The elongate proximal pusher **7012** can be solid or include a lumen to accommodate other delivery assembly components. Nitinol, stainless steel, or other like materials can be used for elongate proximal pusher **7012**, provided the overall design provides sufficient column strength to deliver a shunt **2200** in the shunt delivery shuttle **7000** through a delivery catheter lumen and into a target implant site. The distal portion of the elongate proximal pusher **7012** can include a tapered grind or other features (e.g., cuts, slots, kerfs or the like) to increase the flexibility of such distal portion, which can facilitate shunt translation through the delivery catheter when the catheter is being used in tortuous anatomy. Junction **7014** can be formed by gathering the proximal ends of the filaments **4320** of the distal shuttle portion **7016** of the shunt delivery shuttle **7000** over the distal portion of the elongate proximal pusher **7012** and using a heat shrink material over the filaments and wire, by using a direct connection (e.g., by adhesive or welding, e.g., gathering the filaments over the wire and under a radiopaque marker band), or using any of the shunt-tether interlock configurations disclosed herein.

Alternate embodiments of shunt delivery shuttle **7000** can include any of the anchor **700** configurations disclosed herein as a substitute for the distal shuttle portion **7016** of the shunt delivery shuttle **7000** for translating shunt **2200** through delivery catheter **3304**. For example, as shown in FIGS. **60**A-**63**C, the shunt delivery shuttle **7000** can be formed from a hypo tube with a wall thickness from about 0.0005 inch to about 0.004 inch. The strut width of the shunt delivery shuttle **7000** can range from about 0.0002 inch to about 0.003 inch; the strut width can vary along the length of the shunt delivery shuttle **7000** (e.g., creating a stiffer proximal portion of the shunt delivery shuttle **7000** to facilitate translation of the shunt through the delivery catheter lumen and a more flexible distal portion of the shunt delivery shuttle **7000** radially capture shunt **2200**). FIGS. **62**A-**62**E illustrate alternative junction **7014** between the distal shuttle portion **7016** of the shunt delivery shuttle **7000** and the elongate proximal pusher **7012**, the junction **7014** uses any suitable coupling mechanism or technique.

FIGS. **63**A-C illustrate the shunt and the shunt delivery shuttle according to the embodiments of the invention. FIG. **63**A shows the shunt **2200** and the shunt delivery shuttle **7000** separately, while FIGS. **63**B and **63**C show the interface between the shunt **2200** and the shunt delivery shuttle

7000. The shunt delivery shuttle 7000 is configured to be at least partially positioned within the lumen of, and movable relative to, the delivery catheter. The distal shuttle portion 7016 of the shunt delivery shuttle 7000 is configured to collapse around the elongate shunt body 2203 (FIG. 63B) to thereby transport the shunt body 2203 through the delivery catheter lumen, wherein the distal shuttle portion 7016 self-expands (FIG. 63C) to release the shunt body 2203 when the distal shuttle portion 7000 is advanced out of the delivery catheter lumen through the opening of the tissue penetrating element.

FIGS. 64A-E illustrate another embodiment of the delivery catheter 3304 embodiments described in connection with FIGS. 19A-I, 20, 21A-M, 30A-F. For ease in illustration and disclosure, the features, functions, and configurations of the delivery catheter that are the same as in the delivery catheter of the present disclosure (e.g., FIGS. 19A-I, 20, 21A-M, 30A-F) are incorporated by reference herewith; the differences will be described in further detail below. The delivery catheter illustrated in FIGS. 64A-E has received an elongate guide member 780 through first lumen 3315 of the penetrating element guard or guard member 4000 and delivery catheter 3304. Penetrating element guard 4000 is disposed over penetrating element 3350 to guard against inadvertent punctures in the vasculature while tracking the delivery catheter to the target penetration site in IPS wall 114. As described in connection with FIGS. 20, 21, and 31, the penetrating element guard 4000 can translate proximally over the distal portion of the delivery catheter to expose the penetrating element 3350 at the target penetration site in the IPS.

Penetrating element guard 4000 illustrated in FIGS. 64A-E includes a deflecting element 4030 to deflect penetrating element 3350 away from the elongate guide member 780 and towards a target penetration site in the patient's vasculature. FIG. 64B illustrates a cross-section of a distal portion of the delivery catheter including penetrating element guard 4000 and deflecting element 4030. FIG. 64C illustrates further details of the deflecting element 4030 illustrated in FIGS. 64A-B. Deflecting element 4030 includes proximal 4032 and distal 4034 portions. Distal portion 4034 can facilitate delivery catheter access into narrow or tortuous vasculature.

During a shunt deployment procedure, penetrating element guard 4000 is retracted proximally over the delivery catheter to expose penetrating element 3350 at the target penetration site; as the guard 4000 retracts proximally, the proximal portion 4032 of deflecting element 4032 contacts the bevel of penetrating element 3350. As the clinician further retracts penetrating element guard 4000 proximally, deflecting element 4030 (e.g., proximal portion 4032) deflects penetrating element away from elongate guide member 780. To achieve this deflection for penetrating element 3350, the angle of the proximal portion 4032 of deflecting element 4030 relative to the longitudinal axis of elongate guide member 780, as illustrated by angle "Φ" in FIG. 64C, can range from about five degrees to about 30 degrees, or more. Deflecting element 4030, by increasing the angle of the penetrating element relative to the plane of the elongate guide member 780, increases the distance or separation between the penetrating element tip and guide member 780 (e.g., illustrated as D1 in FIG. 64C). Deflecting element 4030 facilitates tissue puncture in challenging patient anatomies, e.g., in a portion of the IPS 102 or CS 104 that runs relatively parallel to CP angle cistern 138. For example, if the patient has a significant petrous bone overhang that prevents penetration through IPS wall 114 at the first turn 102A of IPS 102 (see FIGS. 2A-B), the clinician can use a delivery catheter and shuttle embodiment as illustrated in FIGS. 64A-E to penetrate IPS wall 114 beyond the petrous bone overhang, for example, between the first 102A and second 102B turns of IPS 102.

Deflecting element 4030 can be added to penetrating element guard 4000 using an ultraviolet light-cured adhesive or epoxy material. Alternatively, penetrating element guard 4000 and deflecting element 4030 can be molded as a single part. Materials for molded embodiments of the penetrating element guard and deflecting element can include Nylon, Pebax, polyurethane, or any other polymeric material disclosed herein for use with guard 4000 or delivery catheter 3304.

FIGS. 64D-E illustrate cross-section views of the delivery catheter 3304 shown in FIGS. 64A-C at reference line "DIE" of FIG. 64B (e.g., through marker band 4015 embedded in guard 4000). As shown in FIGS. 64D-E, delivery catheter 3304 includes a second shuttle pull wire 4012. Pull wire 4012 includes a distal portion 4013 and connection point 4013a, which are illustrated in FIGS. 64D-E. Delivery catheter 3304 includes a fourth lumen 3335 (not shown) configured to receive the second pull wire 4012. A dual pull wire configuration of delivery catheter 3304 can provide smoother penetrating element guard 4000 retraction proximally over penetrating element and provide smoother distal retraction of guard 4000 to re-cover penetrating element 3350 compared to single pull wire embodiments.

FIGS. 65A-C illustrate embodiments of radiopaque markers that enable an clinician to discern delivery catheter 3304 and penetrating element 3350 orientation in the patient's vasculature under flouroscopy. FIG. 65A illustrates marker bands 3370, 3372, and 3374 applied to reinforcing member 1345 of a delivery catheter 3304. FIG. 65B illustrates the patterns used to apply the marker bands shown in FIG. 65A; pattern 3370a of FIG. 65B corresponds to marker 3370 of FIG. 65A, patterns 3376a through 3376j of FIG. 65B corresponds to markers 3372a through 3372j of FIG. 65A, and pattern 3378 of FIG. 65B corresponds to marker 3374 of FIG. 65A. FIG. 65A illustrates catheter assembly alignment features 3374a-c of marker band 3374.

The markers illustrated in FIG. 65A can comprise gold plating (or other radiopaque materials) applied in the patterns reflected in FIG. 65B to reinforcing member 1345. The plating can range in thickness from about 0.0002 inch to about 0.002 inch. Distal marker band 3370 includes orienting features illustrated in FIGS. 65A-B and can be aligned axially with the bevel of penetrating element 3350 to help the clinician discern penetrating element orientation in vivo (e.g., under flouroscopy when deliver catheter 3304 has advanced into IPS 102). Additional dimensions of marker band 3370 and pattern 3370a used to form marker band 3370 are included in FIGS. 65A-B. Markers 3372a through 3372j comprise a series of marker bands placed with equal spacing between each band (e.g., 1 cm spacing between marker bands as illustrated in FIG. 65A) to provide the clinician with a reference point and measurement tool when delivery catheter has navigated to IPS 102. Each marker band 3372a through 3372j is approximately 1 mm wide, although other widths are possible. While FIG. 65A illustrates ten marker bands at equal 1 cm spacing between each band as the bands extend proximally from marker band 3372a, other configurations and spacing are possible. Orienting feature 3374b of marker band 3374 can also be aligned axially with the bevel of penetrating element 3350 to help the clinician discern penetrating element orientation in vivo. Orienting feature 3374c provides a reference point during manufacturing to ensure proper assembly and function of delivery catheter **3304**. For example, elongate guide member **780** and first lumen **3315** of the delivery catheter can be axially aligned to orienting feature **3374***c*. In addition, one or more shuttle pull wires (e.g., pull wire **4010**, pull wire **4012**) and the corresponding pull wire lumens (e.g., third lumen **3325**, fourth lumen **3335**) can be axially aligned to orienting feature **3374***c*. Additional dimensions and features of marker **3374** are included in FIGS. **65**A-B.

FIG. **66** illustrates an embodiment of a handle assembly **6000** for use with a delivery catheter **3304**. Handle assembly **6000** includes three main components: a needle hub **6002**, a double hemostasis valve "Y" connector **6004**, and a vented male Luer cap **6018**; vendor and part number details are provided for these components on FIG. **66**. The proximal end of delivery catheter **3304** extends through needle hub **6002** into the distal hub of Y connector **6004** as illustrated in FIG. **66**. The elongate proximal pusher **7012** of shunt delivery shuttle **7000** extends proximally from the delivery catheter **3304** through a first hemostasis valve **6010** in Y connector **6004** as illustrated in FIG. **66**. Shuttle pull wires **4010** and **4012** extend proximally from their respective lumens in delivery catheter **3304** through a second hemostasis valve **6020** in Y connector **6004**. The proximal ends of shuttle pull wires **4010**, **4012** extend through a female Luer lock and are fixed (e.g., welded, bonded with adhesive) to the underside of male Luer cap **6018**. Hypotubes are used to provide additional support to shuttle pull wires **4010**, **4012** in the second hemostasis valve portion **6020** of Y connector **6004**: a smaller hypotube **6012**, **6014** is placed over each of shuttle pull wires **4010** and **4012**. The pull wire and smaller hypotubes are passed through a larger hypotube **6016** shown in FIG. **66**. Hypotubes can have any suitable dimensions compatible with handle **6000** (e.g., standard hypotube gauging, dimensions, and materials can be ascertained from https://www.vitaneedle.com/hypodermic-tube-gauge-chart/). Dimensions and other details of hypotubes **6012**, **6014**, and **6014** are as follows: larger hypotube **6016** is 15 regular wall×1.89"; smaller hypotubes **6012**, **6014** are 26 thin wall×2.05 inches. The hypotubes **6012**, **6014**, and **6014** subassembly in the second hemostasis valve **4020** portion of Y connector **6004** provides additional support and column strength for shuttle pull wires **4010**, **4012** to enable smooth and consistent proximal and distal actuation of penetrating element guard **4000** via cap **6018**.

When handle assembly **6000** is in use with a delivery catheter **3304**, unscrewing cap **6018** from Luer lock **6022** initiates proximal retraction of penetrating element guard **4000**; after unscrewing cap **6018** from Luer lock **6022**, the clinician can pull proximally on cap **6018** to further retract guard **4000** over penetrating element **3350**. The clinician can then use delivery catheter **3304** to penetrate IPS wall. Handle assembly **6000** includes an aspiration/flush port **6006** that includes a lumen fluidically contiguous with second lumen **3305** of delivery catheter **3304**; by attaching a syringe (e.g., 1 ml syringe) to the proximal end of port **6006**, the operator can aspirate CSF from CP angle cistern **138**, through penetrating element lumen **3355**, delivery catheter lumen **3305**, and port **6006** to observe CSF collecting in the syringe and confirm penetration through IPS wall into the subarachnoid space; alternative embodiments of handle assembly **6000** do not include aspiration/flush port **6006**. The shunt delivery shuttle **7000** can be used to advance shunt **2200** from delivery catheter lumen **3305** and penetrating element lumen **3355** until distal anchoring mechanism **2229** deploys in CP angle cistern **138**. Port **6006** can also be used to flush saline or contrast through lumen **3305** and out of penetrating element lumen **3355** into the patient's vasculature at different points during the shunt implant procedure. By reversing the foregoing sequence described for cap **6018** (e.g., pushing distally on cap **6018** and screwing cap **6018** onto Luer lock **6022**, the operator can advance guard **4000** distally clinician and re-cover penetrating element **3350** (e.g., after shunt implantation and while withdrawing delivery catheter from the patient).

It should be appreciated that if the clinician inadvertently causes a tear in IPS wall **114**, the clinician may elect to abort the procedure. If using an embodiment of anchor **700** that includes an outer polymeric layer that covers the cells of the anchor and a guide member **780** that can detach from anchor **700**, he can, redeploy anchor **700** in the sinus lumen across the tear and leave the anchor **700** in the IPS **102** by detaching guide member **780**; in this scenario, the anchor can prevent venous blood from leaving into the subarachnoid space and/or uncontrolled CSF leaking from the subarachnoid space into the venous system.

FIGS. **67**-A-H illustrates alternative delivery catheter, pusher member **3310** and shunt **2200** interfaces, and respective interlocking members **3336**, constructed according to embodiments of the disclosed inventions. As shown in FIG. **67**A, the interlocking member **3336** of the pusher **3310** engages the outer surface of the shunt **2200**, which radially compresses without longitudinally stretching the shunt **2200** and thereby reduces friction of the shunt **2200** with the delivery catheter inner wall.

In FIGS. **67**B-C, the interlocking member of the pusher **3310** engages the outer surface of the delivery catheter. In these embodiments, friction of the shunt **2200** with the delivery catheter may be reduced and the valve (not shown) of the shunt would be not engaged with the pusher member **3310**, since the interlock member is mounted on the outer surface of the catheter. In alternative embodiments, the interlocking member **3336** of the pusher depicted in FIGS. **67**B-C can be constrained within the lumen of a delivery catheter, as previously described in connection with other pusher embodiments disclosed herein.

As shown in FIG. **67**D-E, the shunt **2200** may be further compressed (e.g., folded, bent, or the like) within the lumen of the delivery catheter **3304** for more efficient packing during delivery of the shunt at the target site.

Alternatively or additionally, the shunt **2200** may be compressed during delivery by the shunt delivery shuttle **7000** having a stent-like structure, as shown in FIGS. **67**F-G. In these embodiments, the shunt comprises a polymeric body and anchoring mechanism (e.g., silicon) as it will be described in further detail below.

In yet another alternative embodiment, the interlocking members **3336** of the pusher and the interlocking members **3337** of the shunt include mating elements, such as a protrusion and a slot, as shown in FIGS. **67**H-I. The engagement of the interlocking members may be further assisted by a reduced inner diameter of the delivery catheter (not shown), magnetic elements, or the like.

Although particular embodiments have been shown and described herein, it will be understood by those skilled in the art that they are not intended to limit the present inventions, and it will be obvious to those skilled in the art that various changes, permutations, and modifications may be made (e.g., the dimensions of various parts, combinations of parts) without departing from the scope of the disclosed inventions, which is to be defined only by the following claims and their equivalents. The specification and drawings are, accordingly, to be regarded in an illustrative rather than restrictive sense. The various embodiments shown and described herein are intended to cover alternatives, modifications, and equivalents of the disclosed inventions, which may be included within the scope of the appended claims.

The invention claimed is:

1. An endovascular shunt implantation system, comprising:

a guide member having a distal portion configured for being deployed in an inferior petrosal sinus (IPS) of a patient;

a delivery catheter movably coupled to the guide member, such that the delivery catheter is translatable relative to the distal portion of the guide member within the IPS, wherein a distal end of the delivery catheter comprises a tissue penetrating element;

a guard member at least partially disposed over, and movable relative to, the tissue penetrating element, the guard member having an open distal end portion configured to allow passage of the tissue penetrating element therethrough, the guard member distal end portion including an inner surface feature configured to deflect the tissue penetrating element away from the guide member when the delivery catheter is translated distally relative to the guard or when the guard is withdrawn proximally relative to the tissue penetrating element; and

a shunt delivery shuttle at least partially positioned within a lumen of, and movable relative to, the delivery catheter, the shunt delivery shuttle comprising an elongate proximal pusher coupled to a distal shuttle portion configured to collapse around an elongate shunt body to thereby transport the shunt body through the delivery catheter lumen, wherein the distal shuttle portion self-expands to release the shunt body when the distal shuttle portion is advanced out of the delivery catheter lumen.

2. The endovascular shunt implantation system of claim **1**, further comprising an expandable anchor configured for being deployed in a dural venous sinus of the patient at a location distal to a target penetration site located on a curved portion of the IPS wall, wherein the elongate guide member is coupled to, and extends proximally from, the anchor.

3. The endovascular shunt implantation system of claim **2**, further comprising a guide member pusher tool configured for translating the respective guide member and anchor relative to the IPS, wherein the pusher tool comprises

a handle having a lumen extending therethrough; and

a tubular body portion coupled to the handle, the tubular body portion comprising a lumen that is contiguous with or otherwise extends through the handle lumen, the respective handle and tubular body lumens being configured to receive the guide member,

wherein the handle is configured to allow selective engagement and release of a portion of the guide member extending proximally through the handle lumen for thereby pushing the guide member, and thus the anchor, distally.

4. The endovascular shunt implantation system of claim **2**, wherein the dural venous sinus comprises the IPS.

5. The endovascular shunt implantation system of claim **3**, wherein the handle comprises a proximal facing surface configured to mate with a human thumb or finger in order to selectively engage or release the guide member using said thumb of finger.

6. The endovascular shunt implantation system of claim **1**, wherein the guard member comprises

a tubular guard body having a first guard body lumen or recess configured to receive the tissue penetrating element, and

a plurality of pull wires, each pull wire having a distal portion fixed within or otherwise attached to the guard body, wherein the pull wires are configured to translate the guard body proximally or distally relative to the delivery catheter so as to at least partially expose or cover, respectively, the tissue penetrating element.

7. The endovascular shunt implantation system of claim **1**, wherein the open distal end portion of the guard member has a beveled or tapered portion, and wherein the inner surface feature is located on said beveled or tapered portion.

8. The endovascular shunt implantation system of claim **1**, wherein the guard member comprises a lumen configured to accommodate passage therethrough of the guide member.

9. The endovascular shunt implantation system of claim **1**, further comprising an endovascular shunt device, the shunt device comprising

an elongate shunt body held within the collapsed distal shuttle portion of the shunt shuttle within the delivery catheter lumen,

and a distal shunt anchor coupled to a distal end of the shunt body and extending distally from the distal shuttle portion of the shunt shuttle, wherein the distal shunt anchor self-expands when advanced out of the delivery catheter lumen through the opening of the tissue penetrating element.

10. The endovascular shunt implantation system of claim **9**, wherein the shunt device further comprises one or more cerebrospinal fluid (CSF) intake openings in a distal portion of the shunt that are in fluid communication with a shunt lumen extending through the shunt body, the shunt body comprising one or more longitudinal slits configured to allow egress therethrough of CSF in the shunt lumen if a fluid pressure within the shunt lumen exceeds a body fluid pressure external of the one or more slits, and wherein a proximal end of the shunt body is fluidly sealed.

11. The endovascular shunt implantation system of claim **10**, wherein the shunt device further comprises a tubular connector having a proximal portion secured to a distal end of the shunt body, a distal portion secured to the distal shunt anchor, and an open distal end located within the distal shunt anchor, the open distal end of the tubular connector comprising the one or more CSF intake openings.

12. The endovascular shunt implantation system of claim **11**, wherein the tubular connector is radiopaque or otherwise has one or more radiopaque elements coupled thereto.

13. The endovascular shunt implantation system of claim **9**, wherein the shunt body comprises a flexible unreinforced polyurethane-silicone blend or other polymer.

14. The endovascular shunt implantation system of claim **1**, wherein the inner surface feature of the guard member comprises at least a partial bead of material applied to or molded as part of an inner surface of the guard member.

15. An endovascular shunt implantation system, comprising:

a guide member having a distal portion configured for being deployed in an inferior petrosal sinus (IPS) of a patient;

a delivery catheter movably coupled to the guide member, such that the delivery catheter is translatable relative to the distal portion of the guide member within the IPS, wherein a distal end of the delivery catheter comprises a tissue penetrating element, the delivery catheter comprising a lumen in communication with an opening in the tissue penetrating element; and a guard member at least partially disposed over, and movable relative to, the tissue penetrating element, the guard member having an open distal end portion configured to allow passage of the tissue penetrating element therethrough, the guard member distal end portion including an inner surface feature configured to deflect the tissue penetrating element away from the guide member when the delivery catheter is translated distally relative to the guard or when the guard is withdrawn proximally relative to the tissue penetrating element.

16. The endovascular shunt implantation system of claim **15**, wherein the guard member comprises

a tubular guard body having a first guard body lumen or recess configured to receive the tissue penetrating element, and

one or more of pull wires, each having a distal portion fixed within or otherwise attached to the guard body, wherein the one or more pull wires are configured to translate the guard body proximally or distally relative to the delivery catheter so as to at least partially expose or cover, respectively, the tissue penetrating element.

17. The endovascular shunt implantation system of claim **15**, wherein the open distal end portion of the guard member has a beveled or tapered portion, and wherein the inner surface feature is located on said beveled or tapered portion.

18. The endovascular shunt implantation system of claim **15**, wherein the guard member comprises a lumen configured to accommodate passage therethrough of the guide member, and wherein the inner surface feature of the guard member comprises at least a partial bead of material applied to or molded as part of an inner surface of the guard member.

19. An endovascular shunt implantation system, comprising:

a guide member having a distal portion configured for being deployed in an inferior petrosal sinus (IPS) of a patient;

a delivery catheter movably coupled to the guide member, such that the delivery catheter is translatable relative to the distal portion of the guide member within the IPS, wherein a distal end of the delivery catheter comprises a tissue penetrating element, the delivery catheter comprising a lumen in communication with an opening in the tissue penetrating element; and

a shunt delivery shuttle at least partially positioned within the lumen of, and movable relative to, the delivery catheter, the shunt delivery shuttle comprising an elongate proximal pusher coupled to a distal shuttle portion configured to collapse around an elongate shunt body to thereby transport the shunt body through the delivery catheter lumen, wherein the distal shuttle portion self-expands to release the shunt body when the distal shuttle portion is advanced out of the delivery catheter lumen through the opening of the tissue penetrating element.

20. The endovascular shunt implantation system of claim **19**, wherein the elongate proximal pusher of the shunt delivery shuttle comprises a lumen.

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